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Stock Assessment of Georges Bank (5Zhjmn) Yellowtail Flounder for 2005

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ABSTRACT

The combined Canada/US yellowtail flounder (*Limanda ferruginea*) catch increased from 1995 to 2001 and in 2004 was 7,275 t, 10% more than the 6,632 t caught in 2003. Adult biomass (ages 3+) has generally increased from 2,000 t in the mid 1990s but remains low at about 10,000-19,000 t in 2005, indicating that more stock rebuilding is needed. Recruitment has improved compared to the period 1980 to the mid 1990s, averaging 21 to 27 million age-1 fish during the past five years. Fishing mortality for fully recruited ages 4+ has been close to or above 1.0 between 1973 and 1994, declined to less than 0.6 in 2002 and 2003, well above the reference point of $F_{ref} = 0.25$, and increased in 2004 to above 1.0. Truncated age structure in the surveys and change in distribution indicate current productivity may be limited relative to historical levels. Assuming a 2005 catch equal to the 6,000 t quota, a combined Canada/US yield of about 2,100-4,200 t in 2006 has a neutral risk, about 50%, of exceeding $F_{ref} = 0.25$. A combined yield below about 3,000 t to 3,500 t would be required to ensure a low risk of not achieving a 20% biomass increase from 2006 to 2007.

RÉSUMÉ

Les prises combinées de limande à queue jaune (*Limanda ferruginea*) du Canada et des États-Unis ont augmenté de 1995 à 2001 et elles se chiffraient à 7 275 t en 2004, ce qui était supérieur à celles de l'année précédente (6 632 t). La biomasse des adultes (âges 3+) a généralement augmenté par rapport à ses 2 000 t du milieu des années 1990, mais elle reste faible, se situant alentour de 10 000-19 000 t en 2005, ce qui reflète la nécessité d'un rétablissement du stock. Le recrutement s'est amélioré par rapport à la période allant de 1980 au milieu des années 1990; il s'est chiffré en moyenne à 21-27 millions de poissons d'âge-1 au cours des cinq dernières années. La mortalité par pêche parmi les poissons des âges 4+ pleinement recrutés s'est située alentour ou au-dessus de 1,0 entre 1973 et 1994, puis elle est descendue sous 0,6 en 2002 et 2003, ce qui était bien supérieur au point de référence $F_{réf.} = 0.25$; elle a augmenté en 2004 et dépassé 1,0. La structure d'âges tronquée dans les relevés et le changement dans la distribution révèlent que la productivité actuelle pourrait être limitée par rapport à ses niveaux historiques. Si on se fonde sur des prises égales au quota de 6 000 t en 2005, un rendement combiné du Canada et des États-Unis d'environ 2 100-4 200 t en 2006 représente un risque neutre, soit d'environ 50 %, de dépassement de $F_{réf.} = 0,25$. Un rendement combiné inférieur à environ 3 000-3 500 t serait nécessaire pour que le risque de ne pas atteindre une hausse de 20 % de la biomasse de 2006 à 2007 soit faible.

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INTRODUCTION

The Georges Bank yellowtail flounder *(Limanda ferruginea)* stock is a transboundary resource in Canadian and US jurisdictions. This paper updates the last stock assessment of yellowtail flounder on Georges Bank, completed by Canada and the US (Legault and Stone 2004) taking into account advice from the 2005 benchmark review (TRAC 2005). Last year, the outlook was more uncertain than in previous years due to an increase in the retrospective pattern seen in the age-based analytical assessment and major divergence between the age-based assessment, production model, and forward projecting age structured assessment program (ASAP) results. The increased uncertainty in current stock status, the divergence in model results, and the failure to explain the absence of older fish in the catch gave very little confidence in projection results. The calculated catch for 2005 from the VPA (3,800 t) was thought to be overly optimistic to achieve F_{ref} but was offset by ASAP results that hypothesized a dome-shaped selectivity pattern due to Closed Area II which had a much higher calculated catch for 2005 (8,000 t) under the same F_{ref}.

In 2005, the TRAC conducted a benchmark review of the Georges Bank yellowtail flounder stock assessment with separate meetings to discuss data issues and assessment model formulations (TRAC 2005). A primary objective of the benchmark review was to address the retrospective pattern that had been apparent from assessments conducted during the past several years. As part of this review, a number of important changes were made to the input data used for virtual population analysis (VPA), the main analytical approach used to evaluate the status of this stock. These changes included revision of the DFO survey age-specific indices of abundance for 1987-2003, the inclusion of yellowtail flounder discards from the Canadian offshore scallop fishery for 1973-2003 in the Canadian catch at age (CAA), and revisions to the US dredge discards. During the second benchmark assessment meeting, several analytical models were reviewed all of which indicated that the catch at age and survey abundance at age show differences which can not be reconciled; suggesting an increase in natural mortality, a large amount of unreported catch, or a change in survey catchability since 1995. The consensus view from this meeting was that management advice for 2005 should be formulated on basis of results from several approaches:

- Analysis of data from survey and fishery (trends in relative F and Z)
- Base run VPA model formulation from 2004 assessment
- Two new VPA model formulations with minor & major changes to base run

The analytical methods used in the current assessment are based on revised model formulations adopted during the 2005 TRAC benchmark review with updated catch information and indices of abundance from both countries.

Yellowtail flounder range from southern Labrador to Chesapeake Bay and are typically caught at depths between 30 and 70 m. A major concentration occurs on Georges Bank from the northeast peak to the east of the Great South Channel. Yellowtail flounder have previously been described as relatively sedentary, although a growing body of evidence counters this classification with off bottom movements (Walsh and Morgan 2004; Cadrin and Westwood 2004), limited seasonal movements (Royce et al. 1959; Lux 1963; Stone and Nelson 2003; C. Glass pers. comm.), and transboundary movements to the east and west across the international boundary (Stone and Nelson 2003; S. Cadrin pers. comm.). On Georges Bank, spawning occurs during late spring and summer, peaking in May. Eggs are deposited on or near the bottom and after fertilization float to the surface where they drift during development. Larvae are pelagic for a month or more, then develop demersal form and settle to benthic habitats. Based on the distribution of both ichthyoplankton and mature adults, it appears that

spawning occurs on both sides of the international boundary. Growth is sexually dimorphic, with females growing at a faster rate than males (Lux and Nichy 1969; Moseley 1986; Cadrin 2003). Yellowtail flounder appear to have variable maturity schedules, with age two females considered 40% mature during periods of high stock biomass to 90% mature during periods of low stock biomass.

Historical and new information as it pertains to the current management unit used to delineate the Georges Bank yellowtail flounder stock was reviewed for the 2005 benchmark assessment. Tagging observations, larval distribution, vital population parameters (i.e. growth, survival, recruitment, reproduction, abundance), and geographic patterns of landings and survey data indicate that Georges Bank yellowtail flounder comprise a relatively discrete stock, separate from those occurring on the western Scotian Shelf, off Cape Cod and southern New England (Royce et al. 1959; Lux 1963; McBride and Brown 1980; Neilson et al. 1986; Begg et al. 1999; Cadrin 2003; Stone and Nelson 2003). Based on new information from the comprehensive review by Cadrin (2003) and recent results from cooperative science/industry tagging programs conducted by Canada and the US, there does not appear to be any justification for redefining the geographic boundaries of the Georges Bank yellowtail flounder stock management unit.

The management unit currently recognized by Canada and the US for the transboundary Georges Bank stock includes the entire bank east of the Great South Channel to the Northeast Peak, encompassing Canadian fisheries statistical areas 5Zj, 5Zm, 5Zn and 5Zh (Fig. 1a) and U.S. statistical reporting areas 522, 525, 551, 552, 561 and 562 (Fig. 1b). Both Canada and the US employ the same management unit. The quota sharing agreement between the two countries requires that catches from all sources be counted against the national allocations, regardless of whether the catch was landed or discarded.

The Fisheries

Exploitation of the Georges Bank stock began in the mid-1930's by the US trawler fleet. Landings (including discards) increased from 400 t in 1935 to 9,800 t in 1949, then decreased in the early 1950s to 2,000 t in 1956, and increased again in the late 1950s (Fig. 2). The highest annual catches occurred during 1963-1976 (average: 17,500 t) and included modest catches by foreign fleets (Table 1). No foreign catches of yellowtail have occurred since 1975. In 1985, the stock became a transboundary resource in Canadian and US jurisdictions. Catches averaged around 3,500 t between 1985 and 1994, then dropped to a record low of 1,183 t in 1995 when fishing effort was drastically reduced in order to allow the stock to rebuild. The US fishery in the management area has been constrained by spatial expansion of Closed Area II in 1994 (Fig. 1b) and by extension to year-round closure in 1995, as well as net regulations and limits on days fished. In 2004, a Yellowtail Special Access Program in Closed Area II opened up the area to a US bottom trawl fishery for the first time since 1995. A directed Canadian fishery began on eastern Georges Bank in 1993, pursued mainly by small otter trawlers (< 20 m). Catches by both nations (including discards) have steadily increased (with increasing quotas) from a record low of 1,183 t in 1995, when the stock was considered to be in a collapsed state, to 7,857 t in 2001. In 2004, combined catches for the US and Canada were 7,275 t.

United States

The principle fishing gear used in the US fishery to catch yellowtail flounder is the otter trawl, but scallop dredges contribute some landings. In recent years, otter trawls caught greater than 98% of total landings from the Georges Bank stock, while dredges caught 0-2% of annual totals. US trawlers that land yellowtail flounder generally target multiple species on the

southwest part of the Bank, and on the northern edge along the western and southern boundaries of Closed Area II. The Special Access Program (SAP) in Closed Area II from June to September accounted for a large portion of the 2004 landings. Current levels of recreational fishing are negligible and there have been no foreign catches since 1995.

In May of 2004 a new electronic dealer reporting system for US landings was implemented. This new reporting system did not allow the typical proration to stock area scheme using logbook data as described in Cadrin et al. (1998) because the gear code was not included in many records. Gear codes were assigned to permits that had only used a single gear based on logbook records. This allowed the typical proration scheme to be used. Examination of patterns of landings reported in the dealer database and those in the logbook records show similar trends in terms of time of year, gear, and port. Thus, there is no indication of a systematic bias in these allocations. Total yellowtail landings (excluding discards) for the 2004 directed fishery were 6,208 t, an increase of 86% from 2003, and the highest landings since 1983 (Table 1; Fig. 2).

Discarding of yellowtail in the US trawl fishery increased in 2004 due to both an overall increase in landings and a prohibition of landings in November and December. The large landings of yellowtail caused fish to be discarded that were slightly above the minimum size regulation as well as those below the minimum size regulation. In 2004, 81% of yellowtail flounder discards originated from the trawl fishery (446 t), while the remainder came from the scallop fishery (104 t). The scallop fishery focused most of its effort in the Mid-Atlantic region, even when a Special Access Program for scallops in Closed Area II was implemented in November and December. Due to the negligible landings of yellowtail in the scallop fishery, the regression method to estimate discards of yellowtail from landings of scallops from the benchmark assessment was employed for this fishery. The trawl fishery estimates of discards were obtained from discard to kept ratios of yellowtail based on observer data. Comparison of these d:k ratios from observers and logbooks showed that logbook values were much less than observer values for similar time periods, but the same pattern over time was present.

Total US catches in 2004, including discards, were 6,757 t. The US quota for fishing year 2004 (1 May 2004 to 30 April 2005) was set at 6,000 t. Monitoring of the US catches relative to the quota was based on Vessel Monitoring Systems (VMS) and a call-in system for both landings and discards. The assessment methodology and the monitoring methodology to estimate landings and discards were compared for a six month period of overlap, July to December 2004. During this period, the assessment methodology estimated catch to be 3,466 t while the monitoring methodology estimated catch to be 3,000 t (13% less).

Canada

Canadian fishermen began directing for yellowtail flounder in 1993. Prior to 1993, Canadian landings were small, typically less than 60 t (Table 1, Fig. 2). Landings of 2,139 t of yellowtail occurred in 1994, when the fishery was unrestricted. After a TAC of 400 t was established, yellowtail landings dropped to 464 t in 1995. Since then both quotas and landings have increased steadily and in 2001 were 2,913 t. The majority of Canadian landings of yellowtail flounder are made by otter trawl from vessels less than 20 m, tonnage classes 1-3. The Canadian fishery generally occurs from June to December, with most landings reported in the third quarter. In 2004, landings were 96 t (against a quota of 1,900 t), and were down 95% from 2003 (Table 1). Unlike other years, Canadian fishermen were unable to find commercial quantities of yellowtail in 2004 and the directed fishery ceased in September.

Flatfish landed as "unspecified" in the Canadian fishery have been significant in previous years, and generally consist of yellowtail on Georges Bank. Neilson et al. (1997) revised the landings data for earlier years of the fishery (1993-1995) to account for catches of unspecified flounder species. The unspecified flounder problem has become less significant recently, due to improved reporting practices. For the 2004 fishery, the proportion of yellowtail catch in unspecified flounder landings was estimated by applying the monthly proportions of known yellowtail landings in 5Zm and 5Zj (based on the ratio of known yellowtail catch to known yellowtail + other flounder species catch) to unspecified flounder landings from matching area/month strata. Total unspecified flounder landings in 2004 estimated to be yellowtail, were 0.1 t and 0.4 t for 5Zj and 5Zm, respectively, and are included as part of the Canadian landings (Table 1).

In 2001, summer flounder (*Paralichthys dentatus*) was captured in the Canadian fishery (mostly August through October), and was reported as "unspecified" since it is uncommon in Canadian waters. This amount (estimated to be 1%) represented 26 t of the total yellowtail catch and was subtracted from the total landings (including unspecified estimated to be yellowtail) to give the revised total of 2,913 t for 2001. In 2004, summer flounder catches of 2.2 t were identified and reported as a separate species in the commercial landings data, so no adjustments to the total yellowtail landings were required.

The Canadian directed fishery for yellowtail is concentrated in the southern half of the Canadian fishing zone, in the portion of 5Zm referred to as the "Yellowtail Hole". Overall, the fishery distribution in 2004 was comparable to that observed over the previous five years, but catches were small throughout 5Zjm (average= 60kg/tow) (Fig. 3).

Bycatch Estimates

The Canadian offshore scallop fishery is considered to be the main source of Canadian yellowtail flounder discards/bycatch on Georges Bank. Discards from the Canadian scallop fishery have not been included in past stock assessments, however, as a result of the recent benchmark review, these data are now incorporated into the Canadian fishery catch and catch at age for 1973-2004. Prior to 1996, landing of groundfish bycatch by the Canadian scallop fishery on Georges Bank was permitted, however, it is generally acknowledged that all the yellowtail flounder bycatch was not landed. To account for the total bycatch for 1973-1995, it was necessary to augment the landings by the scallop fishery with the discarded amounts of bycatch. Management measures established in 1996 prohibit the landing of groundfish (except monkfish) by the Canadian scallop fishery and all bycatch of yellowtail flounder is now discarded. Discards, whether pre or post 1996, are not recorded in the Canadian fishery statistics and can only be estimated from observer deployments.

Prior to 2001, very few Canadian scallop trips on Georges Bank had at-sea observer deployments, with only nine trips monitored from 1991 to 1998. More recently, in response to a Fisheries Resource Conservation Council recommendation, a monitoring program was conducted by the Canadian offshore scallop industry in 2001 and 2002 to gather data on bycatches. Twelve trips were observed which covered all months except January and October. Starting in August 2004, routine observer deployment on vessels participating in the Canadian scallop fishery on Georges Bank was initiated, with a total of five trips observed in 2004.

Van Eeckhaute et al. (*in prep*) provide the methodology used for yellowtail flounder discard estimation from the Canadian scallop fishery from 1973-2004 based on observer data. The analysis was done separately for two periods:

1996-2004: landing of yellowtail flounder not permitted, high observer coverage
1973-1995: landing of yellowtail flounder permitted, low observer coverage

For 1996-2004, when landing of yellowtail flounder was not permitted, effort in the scallop fishery was prorated by the observed discard rate of yellowtail to effort to obtain an estimate of discards. While the available data did not support any unit area trends in discard rates, there appeared to be a tendency for higher discard rates in April, May and June and lower discard rates in November and December. Therefore, the proration was conducted using discard rate by quarter. Quarterly discard rates for periods when no observed trips were available were derived by interpolation and application of a seasonal pattern. To estimate discards for year 1996 and later, the quarterly discard rates were applied to the total quarterly effort of the scallop fleet. For 1973-1995, the number of observed trips was very limited and the ratios were subject to influence by anomalous outliers. An effort-based proration was used without the seasonal factors applied in the 1996-2003 period because that refinement was not considered warranted given the limitations of the available information for this period. The approach used for both periods is dependent on the assumption that the bycatch population density, i.e. the *discard+landed / scallop effort* ratio for observed scallop fishing is representative of that for the scallop fishery as well as on the assumption that discarding practices are representative.

Discard estimates from 1973-2004 averaged 546 t and ranged from a low of 268 t in 1995 to a high of 815 t in 2001 (Table 1). Discards represent nearly all of the Canadian catch from 1973-1992 (Fig 2; Fig. 4, upper panel), and result in a slight increase to the total catch from 1973-2004 compared to the total catch used in the 2004 assessment (Fig. 4, lower panel). When Canadian yellowtail flounder catches are revised to include the discard estimates from the offshore scallop fishery, the annual quota for 1994 to 2003 is exceeded in all years by an average of 440 t (range: 251-683 t). For 2004, the total Canadian catch including estimated discards was 518 t, down 82% from 2003 and well below the 2004 TAC of 1,900 t.

Length and Age Composition

In 2004, the Canadian fishery was well sampled for lengths by sex, with 2,009 measurements available from 8 port samples (Table 2). Sea samples from 1 commercial trip provided an additional 954 length measurements by sex. Examination of the size composition from at-sea samples and port samples collected during the same quarter showed that the size composition by sex was quite similar and that there was a distinct seasonal pattern with more females present in the catch during the 2nd quarter, shifting to male predominance in the 3rd quarter (Fig. 5). This suggests a movement of males into (or females out of) the Yellowtail Hole during the 3rd quarter. Given the similarity between the two sources of size information (i.e. port vs observer), length data from the observed trip was combined with the DFO/Industry port-sampling program to characterize the size composition of the Canadian fishery. The protocol of combining size composition data from both sources has also been used in past assessments.

Canadian at-sea length frequency information for 2004 also indicated that culling on the basis of length was not a major concern in the 2004 fishery (Fig. 5). While the Canadian fishery currently has a minimum fish size limit of 30 cm total length, this size regulation is seldom enforced. Since 1993, the percentage of undersized fish (i.e. < 30 cm by number) has rarely exceeded 4% of the total reported catch and has been below 1% for the past three years (Fig. 6). In 2004, only 0.8% of fish in the Canadian commercial catches were less than 30 cm.

The average size of yellowtail flounder in the Canadian fishery increased between 1994 and 2002 from 33 to 35 cm total length for males and from 35 to 41 cm for females (Fig 7). While the average size of males in the fishery did not change in 2004 (35 cm), the mean size of

females declined to 39 cm. The proportion of males in the catch increased from 25% in 1999 to 65% in 2002, but declined to 52% in 2004.

The number of US port samples increased in 2004, with 7,964 length measurements available from 74 samples (Table 2). This compares with 4,877 measurements from 48 samples in 2003. At-sea sampling also increased in 2004 and provided an additional 19,403 length measurements, which were combined with the port samples to characterize the size composition of the US catch. At-sea sampling was considerably higher in 2004 due to increased observer coverage from the Yellowtail Special Access Program (SAP) in Closed Area II. Landings could not be easily classified as coming from the yellowtail SAP. However, samples from observers could be compared for trips fishing inside and outside the SAP. This comparison showed no difference in size composition of the catch (Fig. 8), so the stratification of SAP or not SAP was not deemed important for length and the usual approach to length and age composition was followed.

The US landings are classified by market category (large, small, and unclassified) and this categorization is used to determine the size and age distributions. Both the amount and the proportion of yellowtail landed in the large market category have increased since 1995 from approximately 50% to approximately 75%. Examination of the size distributions for the two market categories shows some overlap in the 35-40 cm range, but overall discrimination between the groups (Fig. 9). The proportion of the landings within the large market category that are 45 cm and larger has increased since 2000; 5%, 8%, 12%, 22%, 20% for years 2000 through 2004, respectively.

The US discard length frequencies were generated from observed trips, expanded to the total weight of discards by gear type and half year or quarter. No differences in length frequency were observed between trips inside and outside Closed Area II during the Special Access program for trawl gear, with discards during this period dominated by sub-legal fish. In the fourth quarter, trawl discards had a similar length frequency as the third quarter catch because landings were prohibited during most of the fourth quarter.

A comparison of the catch at size by nation indicated that the Canadian fishery has generally captured a higher proportion of smaller-sized fish than the US fishery since 2002 (Figs. 10-11). The Canadian fishery in 2004 was comprised mainly of fish in the 31-45 cm size range, while the USA fishery proportionately captured more large fish (31-52 cm), as was the case in 2003 (Fig. 11). Most of the US fishery catches (87%) and all of the Canadian catches (100%) occurred during the second and third quarters (Table 2). Seasonal and geographic differences between Canadian and US fisheries may account for some of the difference in size composition observed over the past two years. Net selectivity, specifically cod end mesh sizes used by US and Canadian fishers may also influence size composition. The slightly smaller Canadian cod end mesh size (i.e. 155 mm square) has the potential to retain more small fish than the larger cod end mesh used in the US fishery (i.e.165 mm square or diamond).

Although otoliths are used to determine age for Grand Bank yellowtail, scales are the preferred structure for aging Georges Bank yellowtail. During a recent yellowtail flounder aging workshop, it was concluded that otolith thin sections are the preferred structure to use for age determinations for this species on the Grand Banks (Walsh and Burnett 2001). However, precise age determination of Georges Bank yellowtail flounder using otolith thin sections is hampered by the presence of weak, diffuse or split opaque zones and strong checks, which can make interpretation of annuli subjective and difficult (Stone and Perley, 2002). Age determination results from recent inter-laboratory exchanges (i.e. DFO/NMFS and DFO/CEFAS) of scales and otoliths collected during DFO bottom trawl surveys have so far been disappointing

with < 55% agreement on these structures between expert age readers. In 2004, scale samples were collected from the Canadian fishery for aging by the experienced NMFS age reader. A total of 70 male and 92 female ages were used to produce separate-sex age-length keys which were applied to Canadian length samples to construct the catch at age (CAA) by sex for the 2004 commercial fishery. A test for consistency by the NMFS age reader on the Canadian fishery age material indicated 86% agreement with a low CV (2.52).

Prior to 2004, no ALKs are available for the Canadian fishery, and the practice has been to borrow separate sex ALKS based on scale age determinations from the same year NMFS fall survey plus second half US commercial fishery and apply these to the Canadian fishery catch at size by sex. While this protocol differs from that used for US landings, it was considered appropriate if there were sufficient ages in the sexed ALKs. During the 2005 benchmark review of assessment input data, it was considered best practice to pool all available ALK information from US port sampling, US sea sampling and NMFS surveys to compile half-year ALKs that could be applied to the length composition from the Canadian fishery. While the ALK sample sizes for these keys were substantially greater than what was used before, the changes in catch at age were nominal (Fig. 12). No Canadian fishery sampling data is available for years prior to 1993 when landings were low. Therefore, the catch at age for Canadian landings prior to 1993 was derived for combined sexes by multiplying the proportion of Canadian landings to US landings by the US fishery numbers at age.

For the US fishery, sample length frequencies were expanded to total landings at size using the ratio of landings to sample weight (predicted from length-weight relationships by season; Lux 1969), and apportioned to age using pooled-sex age-length keys in half year groups. Landings were converted by market category and half-year while discards were converted by gear and half year, except for trawl in the second half which was split into quarters.

Ages 3, 4 and 5 (2001, 2000 and 1999 year classes, respectively) dominated both Canadian and US catches in 2004, with a greater proportion of fish aged 4 and older and fewer age 2's compared to the 2003 fishery (Fig. 13). Generally the US fishery had a higher percentage of fish aged 4+ in 2004 compared to the Canadian fishery. The mean weight at age (kg) for the Canadian and US fisheries were quite similar (same ALKs are used) and generally were more variable at older ages (5+) from the mid 1980s to the mid 1990s (Figs. 14 & 15). A trend of increasing weight at age is apparent in both fisheries for all ages since 1995, with a slight decline in the most recent year, but generally the mean weights have been less variable during this period compared to pre 1995.

The size and age composition of yellowtail flounder discards from the Canadian offshore scallop fishery were estimated using DFO and NMFS survey length composition adjusted for scallop dredge selectivity as described by Stone and Gavaris (2005). (Note: The actual discarded size composition was used for years when this information was available, i.e. 2001, 2002 and 2004). For each year, the trimmed proportion at size composition from the spring and fall surveys was prorated to the total estimated bycatch at size using the corresponding half year length-weight relationship and the estimated half year bycatch from Van Eeckhaute et al. (in prep). The half year age length keys used for aging yellowtail flounder discards at size from the offshore scallop fishery were developed using the following combined ages: Half 1 US commercial fishery + Half 1 US observer sampling + NMFS spring survey, and Half 2 US commercial fishery + Half 2 US observer sampling + NMFS fall survey.

The estimated discarded catch at age for 1973-2003 was generally dominated by ages 2, 3 and 4, with high numbers of age 1 fish in some years (Fig. 16; Table 3). The weight at age for

discards was fairly consistent for ages 1 through 6, but was somewhat more variable for ages 7 and older due to low numbers of age samples for large fish (Fig. 17; Table 4). Generally, the method was considered to be appropriate for estimating the discarded age composition of yellowtail flounder from the Canadian offshore scallop fishery and the estimated discards at age were added to the Canadian fishery CAA to give the total CAA for Canada.

Overall, the 2004 catch age composition was represented by the 2001 (age 3) and 2000 (age 4) and 1999 (age 5) year classes, with age 4 predominant (Fig. 18, Table 5). Notable in 2004 is the presence of more fish aged 4 and older in the catch. Since the mid 1990s, ages 2-4 have represented most of the exploited population, with very low catches of age 1 fish since the implementation of larger mesh in the cod end of commercial trawl gear.

Fishery mean weights at age for each of the Canadian and US landings and discards were derived using the applicable ALKs, LFs and length-weight relationships. These were then combined for an overall fishery weight at age, weighting by the respective catch at age (Table 6; Fig. 19). A trend of increasing weight at age is apparent for all ages since 1995, with a decline in the most recent year, but generally the mean weights have been less variable during this period compared to pre 1995. Current WAA values are within the range of past WAA calculations since 1973.

ABUNDANCE INDICES

Commercial Fishery Catch

A standardized catch rate series was developed for the Canadian fishery using a multiplicative model that was solved using standard linear regression techniques after *ln* transformation of nominal CPUE (t/hr) data (Gavaris 1980, 1988a). For this analysis, only trips in 5Zm with ≥ 2.0 t of yellowtail landed were included (n=1433), and were assumed to represent directed fishing activity for yellowtail flounder. For the 2004 fishery, only 16 "directed trips" were available for CPUE analysis. A model with main effects of year (1993-2004), month (June-December) and tonnage class (1-3) was used to standardize the Canadian CPUE series:

$$ln(CPUE_{ijk}) = \mu + Year_i + Month_j + Tonnage\ Class_k + e_{ijk}$$

Analysis of variance results (Table 7) indicate that the overall regression and individual main effects were significant ($P < 0.05$) and that the model explained 63% (multiple r^2) of the variability in the data. No trends were apparent in the pattern of residuals (Table 7, bottom) and the standardized series tracked the nominal series (weighted mean) quite well (Fig. 20, upper panel).

Standardized catch rates decreased between 1993 and 1994 but increased by a factor of two between 1994 and 1995, with a further increase in 1996. Catch rates were stable from 1996 to 1998 then increased considerably in 1999 when some of the fleet switched to more efficient flounder gear. In 2000, catch rates dropped sharply, with a continued decline in 2001 to the second lowest level in the series, due to a greater than five-fold increase in effort from 1999 to 2001, and remained at low levels through 2002 and 2003, reaching the lowest level in the series in 2004, when fishery catches were extremely poor. In comparison with the DFO spring survey biomass index for stratum 5Z2 (Canadian portion of the bank <90 m), the CPUE series tracks the index up to 1999, but falls off rapidly thereafter (Fig. 20, lower panel). The Spearman rank correlation coefficient for these two series (1993-2004) was not significant (r_s=0.021; P=0.948; n=12), suggesting that catch rates within the Yellowtail Hole have declined more rapidly in

recent years than the Canadian portion of the bank (< 90 m) as a whole. Notable is the strong decline in the DFO survey index for 5Z2 in 2005 (Fig. 20, lower panel).

During the May 2004 industry consultation, fishermen indicated that catch rates have been low for the past three years (2001-2003), despite a very modest increase in 2002. At the May 2005 industry consultation, it was confirmed that catch rates were very low during the 2004 fishery and that commercial quantities of yellowtail flounder were difficult to find in the Yellowtail Hole area. Although the standardized series provides useful anecdotal information on recent trends in the Canadian commercial fishery catch rates, it is not used as a tuning index for the VPA model. This is because the catch rate series represents relative abundance from only a small geographic area on the Canadian side of the management unit. A comparable CPUE series from the US fishery in combination with the Canadian series would be required in order to develop indices which represent the entire management area, but still may not index abundance due to Closed Area II.

Research Vessel Surveys

Bottom trawl surveys are conducted annually on Georges Bank by DFO in the spring (February) and by the US National Marine Fisheries Service (NMFS) in the spring (April) and fall (October). Both agencies use a stratified random design, though different strata boundaries are defined (Fig. 21). NMFS spring and fall bottom trawl survey catches (strata 13-21), NMFS scallop survey catches (scallop strata 54, 55, 58-72, 74), and DFO spring bottom trawl survey catches (strata 5Z1-5Z4) were used to estimate relative stock biomass and relative abundance at age for Georges Bank yellowtail. Conversion coefficients, which compensate for survey door, vessel, and net changes in NMFS groundfish surveys (1.22 for old doors, 0.85 for the Delaware II, and 1.76 for the Yankee 41 net; Rago et al. 1994) were applied to the catch of each tow.

Biomass indices for the three groundfish surveys track each other reasonably well over the past two decades. The DFO survey biomass series followed an increasing trend from 1995 to 2001 (the highest value in the series), then declined from 2002 through 2004, followed by a slight increase in 2005 (Table 8, Fig. 22). The current level is still considerably higher than that observed during the mid-1990s, when the stock was in a collapsed state. The NMFS spring series is longer, and tracks the DFO series well during the years of overlap up to 1999, then shows a decline through to 2001 followed by a sharp increase in 2002 (Table 9, Fig. 22). Similar to the DFO series, the NMFS spring biomass index follows a sharp decline from 2002 to 2004, the lowest value since 1994, then increases slightly in 2005. The NMFS fall survey, which is the longest running time series, also shows an increase from 1995 to 1999, with a slight drop in 2000 followed by a large increase in 2001 (Table 10, Fig. 22). This series showed a strong decline between 2001 and 2002, but has increased through 2003 and 2004. The NMFS fall index is still at a relatively high level compared to the mid 1990's when the stock was at low levels. Note that both the NMFS spring and fall survey series showed high inter-annual variability during the previous periods of high abundance, the 1960s and 1970s, which may be reflective of the patchy distribution of yellowtail on Georges Bank and the low sampling density of NMFS surveys.

Since 1996, most of the DFO survey biomass and abundance of yellowtail flounder has occurred in Stratum 5Z4, which includes the lower portion of Closed Area II on the US side where no commercial groundfish fishing has occurred from 1995 through 2003 (Fig. 23). Although survey estimates for this stratum tend to be quite variable due to low sampling intensity, there was an increasing trend from 1996 to 2003 followed by a sharp decline in 2004, and then a strong increase in 2005. Some of the decline in 2004 was attributed to reduced sampling of the traditional high abundance area in the eastern part of Closed Area II, since most

of the tows for Stratum 5Z4 in 2004 fell either north or south of this region. Stratum 5Z2 (CDN portion of Georges < 90 m depth) has also shown an increasing trend in biomass and abundance since 1996, but at a lower level than 5Z4. However, the 2005 survey indicates that both biomass and abundance have declined within this strata, despite the fact that there was only a limited Canadian fishery in 2004, and that abundance has increased in 5Z4 where a large US fishery took place in CAII during a special access program in 2004.

The length composition of yellowtail flounder captured in DFO surveys has been fairly consistent, with little change in the average size of males over the past 5 years (2001-2005), and a slight decline in the average size of females from 2004 to 2005 (Fig. 24). During this period, males have averaged 34 cm TL and females have averaged 38-40 cm TL. An increase in abundance is evident for males in 2005 but not for females. Both DFO and NMFS surveys generally show similar size composition with more fish captured in DFO surveys due to higher sampling density (Fig. 25). Yellowtail flounder captured in all three surveys had an average size of 34 cm TL. Throughout the DFO survey time series (1987-2005), the sex ratio has been slightly above 50% for males, but increased from 58% in 2004 to 71% in 2005, the highest level in the series (Fig. 26). The percentage of males is much more variable in the CDN fishery compared to the survey, likely due to seasonal and geographic variation in the distribution of fishing effort.

The average weights at length were examined by sex for three length ranges of yellowtail flounder (29-31 cm, 34-36 cm and 39-41 cm) for DFO surveys conducted from 1987-1991 and 1996-2005 (note: weights were not recorded for the1992-1995 DFO surveys) (Fig. 27). This measure, which is used to reflect condition, has not changed appreciably over the past decade with the exception of a decline from 2003-2005 for the larger size categories.

Age-structured indices of abundance for NMFS spring and fall surveys were derived using survey-specific age-length keys. In the past, age-length keys from NMFS spring surveys have been substituted to derive age composition for same-year DFO spring surveys, since no ages were directly available from the DFO surveys because of difficulties associated with age interpretation from otolith sections (Stone and Perley 2002). To avoid borrowing, NMFS has offered to age material collected on DFO surveys. In 2005, scales were collected during the DFO surveys for age interpretation by the NMFS age reader (as was done in 2004). A total of 212 male and 205 female ages were used to produce separate-sex age-length keys which were applied to abundance at length to generate the 2005 DFO age-specific indices of abundance. A test for consistency by the NMFS age reader on the DFO survey age material indicated 92% agreement with a low CV (1.79).

As part of the 2005 benchmark assessment review for Georges Bank yellowtail flounder, the DFO survey age-specific indices of abundance for 1987-2003 were re-calculated using NMFS spring survey age length keys (traditional method) augmented with additional ages borrowed from first half US port sampling and sea sampling to "fill out" missing ages at length. This was considered the best practice for the available data. The revised DFO indices with the enhanced ALKs showed some differences from age-specific indices used in the 2004 assessment (Fig. 28), but were considered to provide better representation of the age at length, although their inability to track strong/weak year classes is still of concern.

For the DFO, NMFS spring and NMFS fall groundfish surveys, the current year relative abundance for ages 1-2, 3-4 and 5+ was compared to the average abundance for the previous ten years. (Note: The boundaries of Closed Area II (CAII) were included in these plots to illustrate differences in age-specific abundance inside and outside the closed area). In 2005, the area of highest abundance for the DFO survey fell within CAII (Stratum 5Z4) for all age

groups, but over the past 10 years, abundance appears to be similar both inside and outside CAII for most ages, with the possible exception of age 5+ which may have higher abundance within the closed area (Fig. 29). For the 2005 NMFS spring survey, abundance was higher for ages 1-2 and 3-4 in CAII but not age 5+, which had low abundance overall (Fig. 30). Over the past 10 years, the relative abundance of all age groups appears to be similar both inside and outside of CAII. Higher abundance was apparent for all ages in CAII during the 2004 NMFS fall survey (Fig. 31). Over the past 10 years, relative abundance of ages 1-2 and 3-4 was similar inside and outside of CAII, however, age 5+ fish may be more abundant in CAII during the fall. These plots provide some evidence for slightly higher abundance of older fish within the closed area, but whether CAII can be considered to be a refuge for older fish is not clear. Although recent tagging studies (Stone and Nelson 2003; Cadrin 2005) indicate that movement occurs both into and out of CAII across the international boundary, there is little information on residence time within the closed area.

Both the DFO and NMFS spring series show that the 2002 year class (Age 3) is predominant in 2005, and that the overall abundance of ages 3 to 6+ is higher than 2004 (Tables 8-9; Fig. 32). The 2004 NMFS fall survey also shows greater abundance levels of all age groups compared to 2003 (Table 10; Fig. 32). Similar to the 2005 DFO and NMFS spring surveys, the 2002 year class (Age 2) is predominant in the 2004 NMFS fall survey. Overall, age-structured indices from the surveys do not track cohorts well and there are some indications of year-effects within the time series. However there appears to be some consistency with the 2002 year class in the 2004 NMFS fall survey and both 2005 spring surveys.

The NMFS scallop survey is used as an index of "mid-year" age 1 yellowtail recruitment since small yellowtail are a common bycatch in this survey. The time series was updated from the 2004 assessment to include index values for 2004. While the 2004 value shows a decrease from 2003, the trend from 1990-2003 has been of increasing age 1 abundance (Table 11).

Trends in relative fishing mortality and total mortality from the surveys were examined as part of the consensus benchmark formulations agreed to at the second benchmark assessment meeting in April, 2005. Relative fishing mortality (fishery biomass/survey biomass, scaled to the mean for 1987-2004) was quite variable but followed a similar trend for all three surveys, with a sharp decline to low levels in 1995 (Fig. 33). In contrast, calculations of total mortality rates from the surveys for ages 2, 3 and 4-6 are without trend and indicate no reduction in mortality over time (Fig. 34). While these calculations are clearly noisy, they do not show signs of any interventions or overall changes in total mortality rate during the time series, as would be expected from the management measures implemented by both Canada and the US. This may be due to the inherent noisy nature of these surveys or could reflect ineffective management measures.

ESTIMATION OF STOCK PARAMETERS

Assessment results from analyses conducted in the most recent years have displayed retrospective patterns, residual patterns that are indicative of a discontinuity starting in 1995, and fishing mortality rates that are not consistent with the decline in abundance along cohorts that is evident in the survey data. Essentially, the catch at age data and assumed natural mortality cannot be reconciled with the high survey abundance at ages 2 and 3 and low survey abundance at ages 4 and older.

The empirical evidence suggests that significant modifications to population and fishery dynamics assumptions are required to reconcile the observations from the fishery and the

survey. Models that adopt these modifications to assumptions imply major consequences on underlying processes and/or fishery monitoring procedures. The magnitude of implied changes to natural mortality rate, survey catchability relationships and/or unreported catch are so great that it makes the acceptability of models that incorporate these effects suspect.

In view of the reservations about the implications to underlying processes, adoption of a benchmark formulation, that incorporates these modifications to assumptions, as the sole basis for management advice was not advocated (TRAC 2005). Therefore the TRAC recommended that management advice be formulated after considering the results from 3 VPA approaches described below.

1. Base VPA

The Base Virtual Population Analysis (VPA) used revised annual catch at age (including US and Canadian discards), $C_{a,t}$, for ages a = 1 to 6+, and time t = 1973 to 2004, where t represents the beginning of the time interval during which the catch was taken. The VPA was calibrated to bottom trawl and scallop survey abundance indices, $I_{s,a,t}$, for:

s_1 = DFO spring, ages a = 2 to 6+, time t = 1987 to 2005
s_2 = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 1982 to 2005
s_3 = NMFS spring (Yankee 41), ages a = 1 to 6+, time t = 1973 to 1981
s_4 = NMFS fall, ages a = 1 to 6+, time t = 1973.5 to 2004.5
s_5 = NMFS scallop, age a = 1, time t = 1982.5 to 2004.5

Data were aggregated for ages 6 and older to mitigate against frequent zero observations. Two independent sets of software were used for the analyses; the Canadian ADAPT software and the US NFT VPA v2.1.7 software. Results from the two approaches have always been quite similar, but slight differences exist in the minimization routines, treatments of the plus group, and utilization of bias correction. The fishing mortality rate for the 6 plus group was calculated according to the "alpha" method (Restrepo and Legault 1994) in the Canadian ADAPT software, while an average of fishing mortality on younger ages was used in the US NFT VPA software. Canadian scientists and managers have traditionally utilized bias correction in presentation of results, while US scientists and managers have not. Nonetheless, the results have been so similar between the methods that differences often cannot be seen on graphs, but rather must be observed in tables of results.

Both the Canadian and US software packages use the adaptive framework, ADAPT, (Gavaris 1988b) to calibrate the sequential population analysis with the research survey abundance trend results. The model formulation employed assumed that the random error in the catch at age was negligible. The errors in the abundance indices were assumed independent and identically distributed after taking natural logarithms of the values. Zero observations for abundance indices were treated as missing data as the logarithm of zero is not defined. The annual natural mortality rate, M, was assumed constant and equal to 0.2 for all ages. The fishing mortality rates for age groups 5 and 6+ were assumed equal. These model assumptions and methods were the same as those applied in the last assessment (Legault and Stone 2004). Both point estimates and bootstrap statistics of the estimated parameters were derived.

2. Minor Change VPA

A VPA using the expanded/revised annual catch at age (including US and Canadian discards), $C_{a,t}$, for ages a = 1 to 12, and time t = 1973 to 2004, where t represents the beginning

of the time interval during which the catch was taken. The error in the catch at age was assumed to be negligible compared to the error in the survey indices. Natural mortality was assumed to be 0.2 for all ages and years.

The VPA was calibrated to bottom trawl survey indices, $I_{s,a,t}$, for:

s_1 = DFO spring, ages a = 4, 5, 6-9, time t = 1987 to 2005
s_2 = NMFS spring (Yankee 41), ages a = 4, 5, 6-9, time t = 1973 to 1981
s_3 = NMFS spring (Yankee 36), ages a = 4, 5, 6-9, time t = 1982 to 2005
s_4 = NMFS fall, ages a = 4, 5, 6-9, time t = 1973.5 to 2004.5
s_5 = NMFS scallop, age a = 1, time t = 1982.5 to 2004.5

The aggregated ages 6-9 survey indices were compared to ages 6-9 population abundance. The error in the indices were assumed to be independent and identically distributed. The relationship between indices and population abundance for all ages are assumed to be proportional. Population abundance at age 1 in the terminal year was assumed equal to the geometric mean over the most recent 10 years. Population abundance in the terminal year was estimated for ages 4-6 where the results were deemed reliable and calculated for ages 7-11 based on a weighted average F for ages 4-5. Abundance at ages 2 and 3 in terminal year was based on average PR to fishery for the previous 5 years. The survivors at age 13 in all years were assumed to be few and were set to 1,000 fish.

The Minor Change VPA was not accepted during the 2005 assessment due to a large change in partial recruitment to the fishery for young ages in 2004 compared to the terminal year of the assessment reviewed during the 2005 benchmark assessment methods meeting (Tables 12-13).

3. Major Change VPA

A VPA using the expanded/revised annual catch at age (including US and Canadian discards), $C_{a,t}$, for ages a = 1 to 12, and time t = 1973 to 2004, where t represents the beginning of the time interval during which the catch was taken. The error in the catch at age was assumed to be negligible compared to the error in the survey indices. Natural mortality was assumed to be 0.2 for all ages and years.

The VPA was calibrated to bottom trawl survey indices, $I_{s,a,t}$, for:

s_1 = DFO spring, ages a = 2 to 5, 6-9, time t = 1987 to 1994
s_2 = DFO spring, ages a = 2 to 5, 6-9, time t = 1995 to 2005
s_3 = NMFS spring (Yankee 41), ages a = 1 to 5, 6-9, time t = 1973 to 1981
s_4 = NMFS spring (Yankee 36), ages a = 1 to 5, 6-9, time t = 1982 to 1994
s_5 = NMFS spring (Yankee 36), ages a = 1 to 5, 6-9, time t = 1995 to 2005
s_6 = NMFS fall, ages a = 1 to 5, 6-9, time t = 1973.5 to 1994.5
s_7 = NMFS fall, ages a = 1 to 5, 6-9, time t = 1995.5 to 2004.5
s_8 = NMFS scallop, ages a = 1, time t = 1983.5 to 1994.5
s_9 = NMFS scallop, ages a = 1, time t = 1995.5 to 2004.5

Splitting the survey time series at 1995 could not be justified based on changes in the survey design or implementation, but rather are considered to be aliasing unknown mechanisms causing the retrospective pattern in the Base VPA. The aggregated ages 6-9 survey indices were compared to ages 6-9 population abundance. The error in the indices was assumed to be independent and identically distributed. The relationship between indices and population

abundance for ages 4 and older was assumed to be proportional while that for younger ages (1-3) was permitted to be a power relationship. Population abundance at age 1 in the terminal year was assumed equal to the geometric mean over the most recent 10 years. Population abundance in the terminal year was estimated for ages 2-6 where the results were deemed reliable, and calculated for ages 7-11 based on a weighted average F for ages 4-5. The survivors at age 13 in all years were assumed to be 1,000 fish.

Diagnostics

The population abundance estimates for the Base VPA show greater relative error in model fit (43%) and relative bias (8%) for age 2 while the relative error for ages 3-5 is lower (33-37%) and the bias is smaller (3-5%) (Table 14). The population abundance estimates for the Major Change VPA show greater relative error (21% age 2 to 87% age 6) and relative bias (<1% age 2 to 24% age 6) in model fit with increasing age (Table 15). Survey calibration constants (q's) for the Base VPA decline at older ages for the DFO survey but continue to increase with increasing age for both NMFS surveys. Survey calibration constants (q's) for the Major Change VPA are considerably higher in the recent period (1995 to present) for all three surveys, particularly for ages 1-3, which are fitted to the model with a power function.

The average magnitude of residuals for the 2005 DFO and NMFS spring surveys from the Base VPA showed some improvement over 2004, being more mixed (both positive and negative) and smaller in magnitude (Fig. 35). Most of the residuals were positive for the 2004 NMFS fall survey, they were also smaller in magnitude compared to the 2003 fall survey. In general the Base VPA model predicts higher abundance than surveys prior to1995, then lower abundance up to 2003, then higher again for older ages in recent years. Although this pattern has shown some improvement in the current assessment, there is concern that these large residuals will impact parameter estimates of current abundance. The residual pattern for the Major Change VPA has improved compared to Base VPA and has become more mixed (fewer positives) since 1994 as expected by splitting the survey time series in 1995 (Fig. 36). The average magnitude of residuals has also has also decreased compared to the Base VPA.

Retrospective analysis for the Base VPA indicates a strong tendency to underestimate fishing mortality on ages 4-5 and to overestimate spawning stock biomass and age 1 recruitment (Fig. 37). Although the magnitude of the retrospective pattern from 2003 to 2004 is much less than in previous years, the Base VPA continues to display a retrospective pattern, updating population biomass estimates to lower values than previously determined and compromising interpretation of results. Retrospective analysis for the Major Change VPA did not exhibit a consistent retrospective pattern, updates were both above and below previously estimated values (Fig. 38).

STOCK STATUS

Virtual Population Analysis

Results from the Base VPA and Major Change VPA model formulations were used to evaluate the status of the stock in 2004. For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias and used to construct the history of stock status from the Canadian ADAPT software (Tables 16-19). Since the percent bias was low for almost all estimates, the bias corrected estimates are not much different from the non-bias corrected estimates. In the absence of an unbiased point estimator with optimal statistical properties, this approach was considered preferable by Canadian, but not US, scientists and managers. The

fishery weights at age, assumed to represent mid-year weights, were used to derive beginning of year weights at age (Table 20), and these were used to calculate beginning of year population biomass (Tables 21-22). In the US, spawning stock biomass is the preferred metric for biomass and is computed assuming maturity at age and the proportion of mortality within a year that occurs prior to spawning (p). These results and status determinations were also reported as a part of the 2005 Groundfish Assessment Review Meeting (GARM) held in Woods Hole 15-19 August 2005.

Beginning of year population biomass (Ages 1+) declined from about 32,000 t in 1973 to a historic low of about 4,000 t in 1988 and has subsequently increased to either 22,000 t (Base VPA) or 13,000 t (Major Change VPA) at the beginning of 2005 (Tables 21-22). Age 3+ (adult) biomass followed a similar trend, and either continued its increase from a low of 2,222 t in 1995 to 19,079 t in 2005 (Base VPA) or else increased from a low of 2,088 t in 1995 to 11,587 t in 2001 and fluctuated about 10,000 t since then (Major Change VPA) (Fig. 39). Spawning stock biomass in 2004 was estimated at 14,185 t (Base VPA) or 8,475 t (Major Change VPA). However, the retrospective pattern observed in the Base VPA has resulted in decreases to the terminal year spawning stock biomass to lower levels when updated, averaging 34% decrease over the past 5 years (range: 16% to 59% decrease) with the most recent update exhibiting a 24% decrease. In contrast, the Major Change VPA retrospective results have been both positive and negative over the past 5 years, averaging a 5% increase (range: 30% decrease to 39% increase), with the most recent update exhibiting a 39% increase.

Age 1 recruitment has improved compared to the period 1980 to the mid 1990s, averaging 25 million age-1 fish (Base VPA) or 21 million age-1 fish (Major Change VPA) during the past five years (Figure 39; Tables 16-17). Previous assessments had indicated the presence of some larger recruitment for these years, but their magnitudes have subsequently been estimated to be much smaller. Current indications for the 2003 year class (estimated at 14 or 15 million recruits for Base and Major Change VPA's, respectively) indicate that it may be of lower strength than year classes from the past 5 years, but given the strong retrospective pattern observed in the current and previous assessments, the strength of this year class may be even lower.

Fishing mortality for fully recruited ages 4+ has been close to or above 1.0 between 1973 and 1994, declined to less than 0.6 in 2002 and 2003 from both VPAs, well above the reference point of F_{ref} = 0.25, and increased in 2004 to above 1.0 (Fig. 40, upper panel). This contrasts with the perception of fishing mortality below F_{ref} from previous assessments. Noteworthy is that the lack of trend in the total mortality estimates from the surveys (Fig. 34) is not consistent with the VPA results since 1994, while the pattern exhibited by the relative F is similar (Fig. 33). The fully recruited (4+) exploitation rate averaged 62% (Base VPA) or 64% (Major Change VPA) from 1972-1994, underwent a strong decline in 1995, but increased dramatically in 2004 and is now estimated at 63% (Base VPA) or 77% (Major Change VPA), which is well above the 20% exploitation equivalent to F_{ref} (Fig. 40, lower panel).

FISHERY REFERENCE POINTS

Yield per Recruit Reference Points

Although the yield per recruit analysis was not updated this year, an estimate of $F_{0.1}$ for ages 4+ was calculated from the past yield per recruit analysis of Neilson and Cadrin (1998). ($F_{0.1}$ for ages 4+ = 0.25; exploitation rate=20.0%). This is the same value as the F_{MSY} proxy of $F_{40\%MSP}$ used for US management (NEFSC 2002).

Stock and Recruitment

There is evidence of reduced recruitment at low levels of age 3+ biomass (Fig. 41). However, management actions by both countries appear to have been successful in building the population to levels where the probability of good recruitment may be enhanced. Based on the spawning stock biomass and recruitment relationship observed in a previous stock assessment, the B_{MSY} level of 58,800 t of spawning stock biomass was set as the rebuilding goal in the US for this stock (NEFSC 2002). Current levels of SSB are considerably lower than the rebuilding goal.

OUTLOOK

Yield was projected using the bias adjusted 2005 beginning of year population abundance estimates, assuming a 2005 catch equal to the 6,000 t quota. Recruitment in 2005 and 2006 was set equal to 21.0 million (Base VPA) or 18.6 million (Major Change VPA) age-1 fish (geometric mean of the previous ten years), and fishery partial recruitment was estimated as the average of the previous three years. Projected total Canada/US yield at F_{ref}= 0.25 in 2006 would be 4,227 t (Base VPA; Table 23) or 2,121 t (Major Change VPA; Table 24). If fished at F_{ref} in 2006, the total biomass is projected to increase slightly from 22,132 t in 2006 to 24,645 t by the beginning of 2007 (Base VPA) or from 11,940 t in 2006 to 15,342 t at the beginning of 2007 (Major Change VPA). The 2005 quota of 6,000 t causes projected fully recruited F to be above F_{ref} in 2005 under both models.

The outlook is provided in terms of the possible consequences for alternative catch quotas in 2006 with respect to the harvest reference points. Uncertainty about stock size generates uncertainty in forecast results. This uncertainty is expressed in the outlook as the risk of exceeding F_{ref} = 0.25 and as the risk that 2007 beginning of year biomass for ages 3+ would be less than a 20% increase over the 2006 biomass. The risk calculations provide a general sense of the uncertainties and assist with evaluating the consequences of alternative catch quotas. These calculations do not include uncertainty due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting or the possibility that the model may not reflect the stock dynamics closely enough. Also, the risk calculations are dependent on the model assumptions and data used in the analyses. The assumptions in the two model formulations used were deemed plausible. The consequences of adopting action on the basis of one model if the other model was more appropriate can be evaluated from the risk results. A combined Canada/US yield of about 4,200 t in 2006 has a neutral risk, about 50%, of exceeding F_{ref} according to the Base VPA but would result, with almost certainty, in exceeding F_{ref} according to the Major Change VPA (Fig. 42). A combined yield as low as 2,100 t in 2006, would be required to achieve a neutral risk of exceeding F_{ref} according to the Major Change VPA. A combined yield below about 3,000 t or about 3,500 t would be required to ensure a low risk of not achieving a 20% biomass increase for the Base VPA and Major Change VPA respectively.

If the Base VPA overestimates biomass, as indicated by the retrospective pattern, then calculated catch quotas for 2006 will be overly optimistic to achieve the F reference level. Currently, it is not possible to predict what the retrospective adjustment for 2006 will be. However, if the past five year average of 34% was applied to adjust the Base VPA catches, the 2006 TAC would be closer to the TAC from the Major Change VPA. Medium term projections were not conducted due to uncertainties in the assessment including future recruitment.

Age structure, fish growth, and spatial distribution reflect stock productivity. The current age structure indicates that very little rebuilding of ages 5 and older has occurred and that the population is still dominated by younger ages 1 through 4 (Fig. 43). Both VPA formulations estimate far fewer older fish (6+) in comparison with the population at equilibrium, which is inconsistent with the perception of recent low exploitation. The spatial distribution patterns in 2004/2005 suggest a westward shift. Truncated age structure in the surveys and change in distribution indicate current productivity may be limited relative to historical levels.

MANAGEMENT CONSIDERATIONS

This assessment is hampered by inconsistencies between the age structure of the catch and the age-specific indices of abundance. Although the catch of old fish has increased in the most recent year, it is still less than would be expected given the increases seen in the age-specific indices of abundance. The noisy character of the indices cause difficulty in tuning age structured models.

Consistent management by Canada and the US is required to ensure that conservation objectives are not compromised.

Both VPA formulations have difficulties with interpretation (see benchmark report for full details, TRAC 2005). The Base VPA has a strong pattern in residuals and a strong retrospective pattern. The Major Change VPA adds parameters to decrease these patterns in residuals and the retrospective, but the mechanism for the changes in survey catchability are not easily explained. These changes in survey catchability are most appropriately thought of as an aliasing of an unknown mechanism that produces a better fitting model.

Catching the TAC of 6,000 t in 2005 will result in a fishing mortality rate above $F_{ref} = 0.25$ under both VPA formulations (0.40 Base, 0.82 Major Change). With an assumed total catch of 6,000 t in 2005, the combined Canada/US 2006 catch at F_{ref} would be 2,100-4,200 mt.

The benchmark review was unable to reconcile some of the conflicting results from last year's assessment. While there is still uncertainty about which model to use, concordance between the results from the two models gives more confidence in the determination of status than in the 2004 assessments. Both models indicate that more stock rebuilding is necessary.

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Table 1. Annual catch (000s t) of Georges Bank yellowtail flounder.

Year	US landings	US discards	Canadian landings	Canadian discards	Foreign Catch	Total Catch
1963	10.990	5.600	-	-	0.100	16.690
1964	14.914	4.900	-	-	0.000	19.814
1965	14.248	4.400	-	-	0.800	19.448
1966	11.341	2.100	-	-	0.300	13.741
1967	8.407	5.500	-	-	1.400	15.307
1968	12.799	3.600	0.122	-	1.800	18.321
1969	15.944	2.600	0.327	-	2.400	21.271
1970	15.506	5.533	0.071	-	0.250	21.410
1971	11.878	3.127	0.105	-	0.503	15.610
1972	14.157	1.159	0.008	0.515	2.243	18.039
1973	15.899	0.364	0.012	0.378	0.260	16.953
1974	14.607	0.980	0.005	0.619	1.000	17.211
1975	13.205	2.715	0.008	0.722	0.091	16.750
1976	11.336	3.021	0.012	0.619	0.000	14.988
1977	9.444	0.567	0.044	0.584	0.000	10.639
1978	4.519	1.669	0.069	0.687	0.000	6.944
1979	5.475	0.720	0.019	0.722	0.000	6.935
1980	6.481	0.382	0.092	0.584	0.000	7.539
1981	6.182	0.095	0.015	0.687	0.000	6.979
1982	10.621	1.376	0.022	0.502	0.000	12.520
1983	11.350	0.072	0.106	0.460	0.000	11.989
1984	5.763	0.028	0.008	0.481	0.000	6.280
1985	2.477	0.043	0.025	0.722	0.000	3.267
1986	3.041	0.019	0.057	0.357	0.000	3.474
1987	2.742	0.233	0.069	0.536	0.000	3.580
1988	1.866	0.252	0.056	0.584	0.000	2.759
1989	1.134	0.073	0.040	0.536	0.000	1.783
1990	2.751	0.818	0.025	0.495	0.000	4.089
1991	1.784	0.246	0.081	0.454	0.000	2.564
1992	2.859	1.873	0.065	0.502	0.000	5.299
1993	2.089	1.089	0.682	0.440	0.000	4.300
1994	1.589	0.158	2.139	0.440	0.000	4.326
1995	0.292	0.038	0.464	0.268	0.000	1.183
1996	0.751	0.071	0.472	0.388	0.000	1.682
1997	0.966	0.058	0.810	0.438	0.000	2.272
1998	1.822	0.116	1.175	0.708	0.000	3.821
1999	1.987	0.484	1.971	0.597	0.000	5.038
2000	3.678	0.408	2.859	0.415	0.000	7.360
2001	3.792	0.337	2.913	0.815	0.000	7.857
2002	2.532	0.248	2.642	0.493	0.000	5.915
2003	3.343	0.373	2.107	0.809	0.000	6.632
2004	6.208	0.548	0.096	0.422	0.000	7.275

Table 2. Port samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2004 from Canadian and US sources.

USA	Port Samples				*Sea Samples*			Landings
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(t)
1	All	18	1,884	454	17	1,997	0	731
2	All	30	3,278	659	19	5,851	0	2,344
3	All	20	2,264	446	45	9,625	0	3,061
4	All	6	538	133	24	1,930	0	71
All	All	74	7,964	1,692	105	19,403	0	6,207
Canada	**Port Samples**				*Sea Samples*			**Landings**
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(t)
1	0	0	0	0	0	0	0	0
2	All	2	500	28	1	954	0	33
3	All	5	1,272	108	0	0	0	63
4	All	1	237	26	0	0	0	0
All	All	8	2,009	162	1	954	0	96

Table 3. Estimates of discards at age (numbers in 000's) for yellowtail flounder bycatch in the Canadian offshore scallop fishery, 1973-2004.

	Age													
Year	1	2	3	4	5	6	7	8	9	10	11	12	6+	Total
1973	12	282	312	190	69	25	5	1	1	0	0		31	**897**
1974	224	527	387	257	97	25	12	2	2	0	0	0	42	**1535**
1975	264	1100	314	146	90	37	14	6	0	1			58	**1971**
1976	20	905	350	77	42	18	17	8	6	1			49	**1444**
1977	48	483	604	117	23	9	5	2	1	0			18	**1293**
1978	303	405	485	229	74	16	7	5	4	0	2		34	**1530**
1979	88	988	333	186	71	26	16	5	5				52	**1718**
1980	9	389	741	99	26	9	1	1	1				12	**1277**
1981	52	367	600	353	57	13	1	2	3				19	**1448**
1982	100	574	344	148	62	6	1	4					12	**1239**
1983	5	237	495	138	49	12	3	8	4				26	**950**
1984	86	98	263	302	202	36	0	22					58	**1009**
1985	317	994	233	160	102	12	3						15	**1821**
1986	19	524	131	35	40	27	0	8					36	**785**
1987	16	586	317	203	57	8	6	5	4				23	**1202**
1988	16	586	317	203	57	8	6						14	**1193**
1989	5	612	429	157	40	6	4	0					11	**1253**
1990	12	177	831	172	32	3	3						6	**1229**
1991	251	92	230	479	77	8							8	**1138**
1992	25	736	401	177	82	13	0	1	1				14	**1435**
1993	40	182	416	337	65	11	1						11	**1052**
1994	14	100	136	77	39	5	2	0					7	**374**
1995	36	75	335	219	50	6	4	1					11	**726**
1996	3	157	408	251	68	3	3	2					9	**896**
1997	18	135	269	339	102	10	6	2	1				18	**882**
1998	35	442	504	314	168	63	5	2	0	1			71	**1534**
1999	16	436	410	161	101	38	10	1	1				50	**1175**
2000	3	304	287	151	46	25	10	2	0				37	**828**
2001	30	335	775	294	107	42	18	5	1				66	**1607**
2002	21	248	351	179	77	24	16	11	2	1			54	**931**
2003	13	473	655	285	99	41	22	8	4	1	1		76	**1602**
2004	5	116	309	218	74	36	20	9	6	6	2		79	**800**

Table 4. Estimates of mean weight at age at age (kg) for yellowtail flounder bycatch in the Canadian offshore scallop fishery, 1973-2004.

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1973	0.129	0.281	0.431	0.510	0.604	0.727	0.845	0.872	1.043	0.000	1.170	
1974	0.178	0.332	0.445	0.540	0.623	0.654	0.843	1.059	1.218	0.000	1.496	1.496
1975	0.151	0.319	0.479	0.550	0.643	0.737	0.753	0.748	0.688	0.751		
1976	0.176	0.323	0.562	0.624	0.783	0.800	0.888	1.046	1.155	1.444		
1977	0.162	0.344	0.510	0.615	0.736	0.747	0.760	0.834	0.631	0.704		
1978	0.165	0.306	0.507	0.738	0.866	0.931	1.031	1.139	1.157		0.971	
1979	0.143	0.313	0.484	0.706	0.797	0.893	0.955	1.038	1.421			
1980	0.149	0.294	0.496	0.661	0.853	0.991	1.022	1.048	1.239			
1981	0.145	0.311	0.474	0.622	0.708	1.047	0.899	1.599	1.104			
1982	0.172	0.279	0.467	0.652	0.849	1.203	1.213	1.397				
1983	0.165	0.289	0.460	0.666	0.786	1.081	0.957	1.610	1.239			
1984	0.163	0.227	0.398	0.501	0.686	0.776		1.020				
1985	0.188	0.356	0.534	0.624	0.714	0.755	0.721					
1986	0.216	0.330	0.537	0.776	0.983	1.192	0.704	1.345				
1987	0.195	0.363	0.543	0.735	1.030	1.251	1.099	0.704	0.746			
1988	0.181	0.336	0.562	0.719	0.810	1.021	0.838					
1989	0.105	0.283	0.484	0.712	0.835	0.872	1.005	1.128				
1990	0.192	0.243	0.381	0.623	0.681	0.683	0.855					
1991	0.155	0.218	0.371	0.512	0.712	1.057						
1992	0.177	0.264	0.340	0.550	0.674	0.931		1.303	1.303			
1993	0.138	0.268	0.396	0.517	0.582	0.728	0.747					
1994	0.154	0.226	0.335	0.487	0.628	0.837	0.826	1.496				
1995	0.165	0.222	0.310	0.465	0.612	0.779	0.898	0.532				
1996	0.157	0.257	0.390	0.526	0.689	0.841	1.093	1.324				
1997	0.177	0.287	0.422	0.566	0.730	0.885	0.827	1.218	1.113			
1998	0.176	0.286	0.413	0.539	0.750	0.996	1.124	1.171	0.000	1.397		
1999	0.173	0.334	0.488	0.687	0.819	0.989	1.336	1.496	1.822			
2000	0.169	0.332	0.475	0.661	0.854	0.988	1.049	1.158	1.104			
2001	0.274	0.338	0.449	0.634	0.810	1.051	1.138	1.303	1.433			
2002	0.214	0.346	0.446	0.653	0.842	1.061	1.183	1.359	1.492	1.428		
2003	0.186	0.346	0.459	0.642	0.809	0.959	1.047	1.136	1.324	1.397	1.708	
2004	0.229	0.283	0.418	0.567	0.738	0.920	1.045	1.161	1.140	1.204	1.421	

Table 5. Total catch at age including discards (number in 000's) for Georges Bank yellowtail flounder, 1973-2004.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	Total
1973	359	5175	13565	9473	3815	1285	283	55	23	4	0	0	34037
1974	2368	9500	8294	7658	3643	878	464	106	71	0	0	0	32982
1975	4636	26394	7375	3540	2175	708	327	132	26	14	0	0	45328
1976	635	31938	5502	1426	574	453	304	95	54	11	2	0	40993
1977	378	9094	10567	1846	419	231	134	82	37	10	0	0	22799
1978	9962	3542	4580	1914	540	120	45	16	17	7	6	0	20748
1979	321	10517	3789	1432	623	167	95	31	27	1	3	0	17006
1980	318	3994	9685	1538	352	96	5	11	1	0	0	0	16000
1981	107	1097	5963	4920	854	135	5	2	3	0	0	0	13088
1982	2164	18091	7480	3401	1095	68	20	7	0	0	0	0	32327
1983	703	7998	16661	2476	680	122	13	16	4	0	0	0	28672
1984	514	2018	4535	5043	1796	294	47	39	0	0	0	0	14285
1985	970	4374	1058	818	517	73	8	0	0	0	0	0	7817
1986	179	6402	1127	389	204	80	17	15	0	1	0	0	8414
1987	156	3284	3137	983	192	48	38	26	25	0	0	0	7890
1988	499	3003	1544	846	227	24	26	3	0	0	0	0	6172
1989	190	2175	1121	428	110	18	12	0	0	0	0	0	4054
1990	231	2114	6996	978	140	21	6	0	0	0	0	0	10485
1991	663	147	1491	3011	383	67	4	0	0	0	0	0	5767
1992	2414	9167	2971	1473	603	33	7	1	1	0	0	0	16671
1993	5233	1386	3327	2326	411	84	5	1	0	0	0	0	12773
1994	59	1432	6631	1856	568	95	23	1	0	0	0	0	10666
1995	62	233	1428	986	211	17	23	4	2	0	0	0	2967
1996	54	566	1922	941	234	11	9	3	0	0	0	0	3740
1997	60	745	1502	1827	442	36	55	11	5	0	0	0	4683
1998	64	1496	3224	2134	782	143	26	3	0	2	0	0	7872
1999	37	3694	3583	1731	743	180	34	1	1	0	0	0	10003
2000	155	3840	5985	3120	832	340	43	36	1	0	0	0	14352
2001	284	3065	7622	2824	1093	293	254	23	9	0	0	0	15468
2002	256	4437	3854	1845	670	263	113	62	11	5	0	0	11517
2003	160	3818	4965	2297	777	328	213	93	39	15	1	0	12708
2004	78	1336	3491	4093	2088	919	429	85	73	20	2	0	12613

Table 6. Mean weight at age (kg) for the total catch including US and Canadian discards, for Georges Bank yellowtail flounder, 1973-2004.

Year	Age											
	1	2	3	4	5	6	7	8	9	10	11	12
1973	0.101	0.348	0.462	0.527	0.603	0.690	1.063	1.131	1.275	1.389	1.170	
1974	0.115	0.344	0.496	0.607	0.678	0.723	0.904	1.245	1.090		1.496	1.496
1975	0.113	0.316	0.489	0.554	0.619	0.690	0.691	0.654	1.052	0.812		
1976	0.108	0.312	0.544	0.635	0.744	0.813	0.854	0.881	1.132	1.363	1.923	
1977	0.116	0.342	0.524	0.633	0.780	0.860	1.026	1.008	0.866	0.913		
1978	0.102	0.314	0.510	0.630	0.803	0.903	0.947	1.008	1.227	1.581	0.916	
1979	0.114	0.329	0.462	0.656	0.736	0.844	0.995	0.906	1.357	1.734	1.911	
1980	0.101	0.322	0.493	0.656	0.816	1.048	1.208	1.206	1.239			
1981	0.122	0.335	0.489	0.604	0.707	0.821	0.844	1.599	1.104			
1982	0.115	0.301	0.485	0.650	0.754	1.065	1.037	1.361				
1983	0.140	0.296	0.441	0.607	0.740	0.964	1.005	1.304	1.239			
1984	0.162	0.239	0.379	0.500	0.647	0.743	0.944	1.032				
1985	0.181	0.361	0.505	0.642	0.729	0.808	0.728					
1986	0.181	0.341	0.540	0.674	0.854	0.976	0.950	1.250		1.686		
1987	0.121	0.324	0.524	0.680	0.784	0.993	0.838	0.771	0.809			
1988	0.103	0.328	0.557	0.696	0.844	1.042	0.865	1.385				
1989	0.100	0.327	0.520	0.720	0.866	0.970	1.172	1.128				
1990	0.105	0.290	0.395	0.585	0.693	0.787	1.057					
1991	0.121	0.237	0.369	0.486	0.723	0.850	1.306					
1992	0.101	0.293	0.365	0.526	0.651	1.098	1.125	1.303	1.303			
1993	0.100	0.285	0.379	0.501	0.564	0.843	1.130	1.044				
1994	0.195	0.255	0.348	0.469	0.620	0.810	0.723	1.257				
1995	0.167	0.246	0.352	0.463	0.584	0.766	0.805	0.532	0.810			
1996	0.140	0.292	0.412	0.563	0.721	0.916	1.062	1.287				
1997	0.206	0.319	0.421	0.537	0.690	0.837	0.878	1.184	1.126			
1998	0.184	0.325	0.447	0.543	0.690	0.903	0.932	1.195		1.473		
1999	0.190	0.369	0.503	0.638	0.756	0.900	1.030	1.496	1.822			
2000	0.220	0.379	0.481	0.613	0.762	0.915	1.020	0.996	1.229			
2001	0.225	0.343	0.456	0.624	0.808	1.013	1.023	1.272	1.483			
2002	0.263	0.382	0.489	0.668	0.829	0.983	1.062	1.282	1.389	1.433		
2003	0.226	0.360	0.477	0.652	0.830	0.945	1.033	1.148	1.273	1.432	1.708	
2004	0.194	0.292	0.436	0.581	0.723	0.884	1.001	1.206	1.207	1.306	1.421	

Table 7. ANOVA results from a multiplicative model with main effects for year (1993-2004) month (June-Dec) and tonnage class (TC1-3) for the Canadian yellowtail flounder fishery CPUE.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.791
MULTIPLE R SQUARED..... 0.626

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.185E3	2.185E3	
REGRESSION	19	4.659E2	2.452E1	124.660
YEAR	11	4.383E2	3.984E1	202.568
MONTH	6	2.863E1	4.772E0	24.264
TONNAGE CLASS	2	8.993E⁻1	4.496E⁻1	2.286
RESIDUALS	1413	2.779E2	1.967E⁻1	
TOTAL	1433	2.929E3		

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.	CATCH	EFFORT
1993	⁻1.3727	0.0259	0.276	0.044	111	402
1994	⁻2.1682	0.0019	0.126	0.005	1138	9025
1995	⁻1.1459	0.0052	0.350	0.025	370	1057
1996	⁻0.6235	0.0054	0.590	0.043	369	626
1997	⁻0.5764	0.0033	0.619	0.035	723	1168
1998	⁻0.6886	0.0027	0.554	0.029	1094	1976
1999	⁻0.3848	0.0017	0.750	0.031	1871	2494
2000	⁻1.0388	0.0012	0.390	0.014	2673	6850
2001	⁻1.6728	0.0012	0.207	0.007	2747	13269
2002	⁻1.5665	0.0012	0.230	0.008	2593	11263
2003	⁻1.7413	0.0019	0.193	0.008	1663	8606
2004	⁻2.8765	0.0139	0.062	0.007	71	1150

RESIDUALS

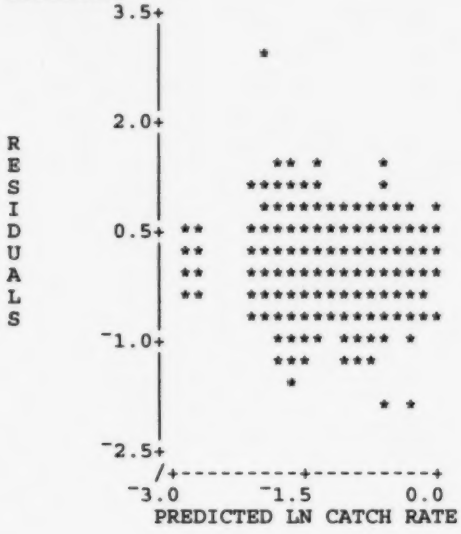

Table 8. Canadian DFO spring survey indices of Georges Bank yellowtail flounder abundance at age (stratified mean #/tow) and stratified total biomass (000s t).

	Age													Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	Total	(000s t)
1987	0.12	0.99	2.00	0.64	0.12	0.00	0.02	0.02	0.00	0.00	0.00	0.00	3.91	1.250
1988	0.00	1.59	1.29	0.76	0.30	0.01	0.02	0.00	0.00	0.00	0.00	0.00	3.96	1.235
1989	0.11	0.94	0.58	0.36	0.09	0.01	0.02	0.01	0.00	0.00	0.00	0.00	2.13	0.471
1990	0.00	2.36	3.38	1.06	0.32	0.01	0.02	0.00	0.00	0.00	0.00	0.00	7.15	1.513
1991	0.02	0.86	1.53	3.23	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.37	1.758
1992	0.06	10.74	3.97	1.03	0.30	0.01	0.00	0.02	0.01	0.00	0.00	0.00	16.14	2.475
1993	0.08	2.24	3.26	4.41	1.64	0.05	0.01	0.00	0.00	0.00	0.00	0.00	11.69	2.642
1994	0.00	6.06	3.46	3.01	0.78	0.13	0.03	0.04	0.00	0.00	0.00	0.00	13.51	2.753
1995	0.21	1.19	4.28	2.55	0.79	0.05	0.04	0.00	0.00	0.00	0.00	0.00	9.11	2.027
1996	0.45	6.65	8.58	6.61	1.01	0.09	0.02	0.03	0.00	0.00	0.00	0.00	23.45	5.303
1997	0.02	9.78	14.67	17.96	4.32	0.53	0.11	0.09	0.00	0.00	0.00	0.00	47.49	13.293
1998	0.89	3.18	4.89	4.50	2.02	0.46	0.03	0.01	0.00	0.02	0.00	0.00	16.01	4.293
1999	0.16	11.84	27.24	7.95	7.30	2.21	0.34	0.04	0.00	0.00	0.00	0.00	57.07	17.666
2000	0.01	9.47	32.90	17.80	5.54	2.96	0.32	0.22	0.00	0.00	0.00	0.00	69.22	19.949
2001	0.29	15.18	47.13	13.35	3.70	1.95	0.90	0.10	0.00	0.00	0.00	0.00	82.60	22.158
2002	0.09	9.67	33.73	11.27	5.97	1.54	0.95	0.38	0.08	0.00	0.00	0.00	63.68	20.699
2003	0.07	6.76	27.36	13.45	3.57	0.86	0.62	0.25	0.12	0.04	0.00	0.00	53.09	16.249
2004	0.03	3.60	16.26	9.21	2.27	0.63	0.23	0.46	0.09	0.00	0.00	0.00	32.79	9.000
2005	0.60	1.60	27.96	20.56	5.70	1.04	0.40	0.10	0.01	0.01	0.00	0.00	57.99	13.357

Table 9. NMFS spring survey indices (stratified mean #/tow) of Georges Bank yellowtail flounder abundance at age and total biomass (stratified mean kg/tow).

	Age													Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	Total	(kg/tow)
1968	0.15	3.36	3.58	0.32	0.08	0.16	0.13	0.00	0.00	0.00	0.00	0.00	7.78	2.813
1969	1.02	9.41	11.12	3.10	1.42	0.45	0.19	0.06	0.00	0.00	0.00	0.00	26.76	11.17
1970	0.09	4.49	6.03	2.42	0.57	0.12	0.19	0.00	0.00	0.00	0.00	0.00	13.91	5.312
1971	0.79	3.34	4.62	3.75	0.76	0.23	0.05	0.01	0.00	0.02	0.00	0.00	13.56	4.607
1972	0.14	7.14	7.20	3.51	1.09	0.05	0.12	0.00	0.00	0.00	0.00	0.00	19.25	6.45
1973	1.93	3.27	2.37	1.06	0.41	0.17	0.02	0.02	0.00	0.00	0.00	0.00	9.25	2.938
1974	0.32	2.22	1.84	1.26	0.35	0.19	0.09	0.00	0.00	0.00	0.01	0.00	6.27	2.719
1975	0.42	2.94	0.86	0.30	0.21	0.07	0.00	0.01	0.00	0.00	0.00	0.00	4.81	1.676
1976	1.03	4.37	1.25	0.31	0.20	0.03	0.05	0.02	0.02	0.00	0.00	0.00	7.27	2.273
1977	0.00	0.67	1.13	0.38	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.00	2.27	0.999
1978	0.94	0.80	0.51	0.22	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	2.49	0.742
1979	0.28	1.93	0.39	0.33	0.06	0.05	0.04	0.00	0.00	0.00	0.00	0.00	3.07	1.227
1980	0.06	4.64	5.76	0.47	0.06	0.04	0.00	0.00	0.00	0.00	0.00	0.00	11.03	4.456
1981	0.01	1.03	1.78	0.72	0.21	0.06	0.00	0.03	0.00	0.00	0.00	0.00	3.83	1.96
1982	0.05	3.74	1.12	1.02	0.46	0.07	0.00	0.03	0.00	0.00	0.00	0.00	6.47	2.5
1983	0.00	1.87	2.73	0.53	0.12	0.09	0.06	0.09	0.00	0.00	0.00	0.00	5.49	2.642
1984	0.00	0.09	0.81	0.89	0.83	0.24	0.00	0.00	0.00	0.00	0.00	0.00	2.87	1.646
1985	0.11	2.20	0.26	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.988
1986	0.03	1.81	0.29	0.06	0.14	0.06	0.00	0.00	0.00	0.00	0.00	0.00	2.37	0.847
1987	0.00	0.13	0.11	0.13	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.329
1988	0.08	0.28	0.37	0.24	0.20	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.566
1989	0.05	0.42	0.74	0.29	0.06	0.02	0.02	0.00	0.00	0.00	0.00	0.00	1.61	0.729
1990	0.00	0.06	1.11	0.39	0.14	0.01	0.04	0.00	0.00	0.00	0.00	0.00	1.76	0.699
1991	0.44	0.00	0.25	0.68	0.27	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.631
1992	0.00	2.01	1.95	0.60	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.74	1.566
1993	0.05	0.29	0.50	0.32	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.482
1994	0.00	0.62	0.64	0.36	0.15	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.66
1995	0.04	1.18	4.81	1.49	0.64	0.01	0.00	0.00	0.00	0.00	0.00	0.00	8.17	2.579
1996	0.03	0.99	2.63	2.70	0.61	0.06	0.00	0.00	0.00	0.00	0.00	0.00	7.02	2.853
1997	0.02	1.17	3.73	4.08	0.70	0.13	0.00	0.00	0.00	0.00	0.00	0.00	9.84	4.359
1998	0.00	2.08	1.05	1.16	0.76	0.32	0.03	0.00	0.00	0.00	0.00	0.00	5.40	2.324
1999	0.05	4.75	10.82	2.72	1.62	0.43	0.33	0.00	0.02	0.00	0.00	0.00	20.74	9.307
2000	0.18	4.82	7.67	2.91	0.81	0.42	0.10	0.00	0.00	0.00	0.00	0.00	16.92	6.696
2001	0.00	2.31	6.56	2.41	0.48	0.35	0.10	0.00	0.00	0.00	0.00	0.00	12.23	5.008
2002	0.19	2.41	12.33	4.08	1.74	0.38	0.41	0.09	0.00	0.00	0.00	0.00	21.62	9.566
2003	0.20	4.37	6.76	2.88	0.44	0.13	0.54	0.20	0.00	0.00	0.00	0.00	15.52	6.719
2004	0.05	0.99	2.18	0.68	0.28	0.11	0.05	0.08	0.00	0.00	0.00	0.00	4.42	1.887
2005	0.00	2.01	5.08	2.40	0.27	0.04	0.05	0.03	0.00	0.00	0.00	0.00	9.88	3.401

Table 10. NMFS fall survey indices (stratified mean #/tow) of Georges Bank yellowtail flounder abundance at age and total biomass (stratified mean kg/tow).

Year	Age														Total	Biomass (kg/tow)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
1963	14.72	7.90	11.23	1.86	0.50	0.28	0.03	0.16	0.07	0.00	0.00	0.00	0.00	0.00	36.75	12.791
1964	1.72	9.72	7.37	6.00	2.69	0.38	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00	28.01	13.625
1965	1.14	5.58	5.47	3.86	1.80	0.16	0.28	0.04	0.00	0.00	0.00	0.00	0.00	0.00	18.33	9.104
1966	8.77	4.78	2.07	0.84	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.60	3.989
1967	9.14	9.31	2.70	1.01	0.31	0.08	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.60	7.577
1968	11.78	11.95	5.76	0.77	0.94	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.25	10.535
1969	8.11	10.38	5.86	1.66	0.55	0.15	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.89	9.278
1970	4.61	5.13	3.14	1.95	0.45	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.37	4.978
1971	3.63	6.95	4.90	2.25	0.55	0.23	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	18.56	6.362
1972	2.42	6.53	4.82	2.10	0.67	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.82	6.328
1973	2.49	5.50	5.10	2.94	1.22	0.42	0.17	0.00	0.03	0.00	0.00	0.00	0.00	0.00	17.87	6.600
1974	4.62	2.85	1.52	1.06	0.46	0.25	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.90	3.734
1975	4.63	2.51	0.88	0.57	0.33	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	8.98	2.365
1976	0.34	1.93	0.48	0.12	0.12	0.03	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	3.08	1.533
1977	0.93	2.16	1.65	0.62	0.11	0.06	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	5.58	2.828
1978	4.73	1.27	0.77	0.41	0.14	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	7.35	2.383
1979	1.31	2.00	0.32	0.12	0.14	0.04	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	4.00	1.520
1980	0.76	5.09	6.05	0.68	0.22	0.16	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	12.99	6.722
1981	1.58	2.33	1.63	0.50	0.12	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.26	2.621
1982	2.42	2.19	1.59	0.42	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.71	2.271
1983	0.11	2.28	1.91	0.47	0.07	0.01	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	4.90	2.131
1984	0.66	0.40	0.31	2.43	0.09	0.03	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	3.93	0.593
1985	1.35	0.56	0.16	0.04	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.19	0.709
1986	0.28	1.11	0.35	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.81	0.820
1987	0.11	0.39	0.40	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.509
1988	0.02	0.21	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.171
1989	0.25	1.99	0.77	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15	0.977
1990	0.00	0.33	1.52	0.28	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.725
1991	2.10	0.28	0.44	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.17	0.730
1992	0.15	0.40	0.71	0.16	0.14	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.59	0.576
1993	0.84	0.14	0.59	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.545
1994	1.20	0.22	0.98	0.71	0.26	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43	0.897
1995	0.28	0.12	0.35	0.28	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.354
1996	0.14	0.35	1.87	0.45	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.88	1.303
1997	1.39	0.53	3.44	2.09	1.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.61	3.781
1998	1.90	4.82	4.20	1.19	0.30	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.48	4.347
1999	3.09	8.42	5.73	1.43	1.44	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.37	7.973
2000	0.63	1.70	4.81	2.42	0.95	0.80	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.34	5.838
2001	3.52	6.27	8.09	2.60	1.72	0.71	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.24	11.553
2002	2.09	5.75	2.13	0.59	0.28	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	10.90	3.760
2003	1.10	5.01	2.81	0.56	0.10	0.09	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	9.77	4.039
2004	0.88	5.51	5.01	2.11	0.92	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.60	5.117

Table 11. NMFS scallop survey index (stratified mean #/tow) for Georges Bank yellowtail flounder age-1 abundance.

Year	Number per tow
1982	0.313
1983	0.140
1984	0.233
1985	0.549
1986	0.103
1987	0.047
1988	0.116
1989	0.195
1990	0.100
1991	2.117
1992	0.167
1993	1.129
1994	1.503
1995	0.609
1996	0.508
1997	1.062
1998	1.872
1999	1.038
2000	0.912
2001	0.789
2002	1.005
2003	0.880
2004	0.330

Table 12. Beginning of year population abundance numbers (000's) for Georges Bank yellowtail flounder from the Minor Change VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2005 from Canadian ADAPT software.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1973	29579	24354	29811	17112	6142	2379	515	182	26	6	2	1	1
1974	51857	23892	15285	12291	5581	1645	804	170	100	2	2	1	1
1975	70056	40320	11060	5131	3270	1343	565	245	45	19	1	1	1
1976	24460	53174	9639	2529	1072	752	469	172	83	14	4	1	1
1977	16851	19452	15175	2999	802	366	214	115	56	20	1	1	1
1978	53583	13455	7807	3090	817	284	95	56	22	13	7	1	1
1979	24860	34905	7835	2323	832	192	125	37	31	3	5	1	1
1980	23543	20064	19141	3033	631	132	12	19	4	2	1	1	1
1981	62671	18989	12834	7037	1112	203	24	5	6	2	1	1	1
1982	22681	51213	14557	5183	1415	159	47	15	2	2	1	1	1
1983	6540	16619	25719	5251	1232	197	70	20	6	2	1	1	1
1984	10781	4721	6470	6298	2089	404	53	45	2	2	1	1	1
1985	16655	8363	2061	1292	737	147	72	3	4	2	1	1	1
1986	8493	12760	2950	745	332	147	55	51	2	3	1	1	1
1987	9001	6792	4739	1406	264	91	49	30	28	2	1	1	1
1988	22539	7228	2630	1103	283	46	32	6	2	2	1	1	1
1989	9803	18003	3232	782	159	32	17	3	2	2	1	1	1
1990	11354	7855	12779	1642	259	33	11	3	2	2	1	1	1
1991	22724	9088	4532	4236	476	87	9	4	2	2	1	1	1
1992	17886	18006	7307	2373	811	54	12	4	3	2	1	1	1
1993	13722	12469	6570	3324	636	133	14	4	2	2	1	1	1
1994	10004	6549	8960	2413	668	157	34	7	2	2	1	1	1
1995	11927	8137	4074	1495	344	52	44	8	4	2	1	1	1
1996	13995	9709	6451	2056	351	95	27	15	2	2	1	1	1
1997	18805	11409	7439	3557	843	80	68	15	10	2	1	1	1
1998	24988	15342	8669	4739	1284	297	34	7	2	4	1	1	1
1999	26642	20400	11212	4210	1974	357	116	5	4	2	1	1	1
2000	20863	21779	13378	5967	1899	951	132	64	4	2	1	1	1
2001	25347	16941	14375	5606	2105	811	474	70	20	2	1	1	1
2002	27535	20496	11112	4981	2072	750	401	162	36	8	1	1	1
2003	4649	22312	12790	5643	2426	1095	378	227	77	20	2	1	1
2004	5934	3662	14828	6027	2565	1289	602	120	102	28	3	1	1
2005	21410	4788	1801	8998	1309	266	244	114	23	19	5	1	1

Table 13. Fishing mortality rate for Georges Bank yellowtail from the Minor Change VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2004 from Canadian ADAPT software.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1973	0.013	0.266	0.686	0.920	1.117	0.885	0.909	0.402	2.469	1.123	0.163	0.000	0.000
1974	0.052	0.570	0.892	1.124	1.224	0.868	0.987	1.131	1.453	0.000	0.138	0.166	0.000
1975	0.076	1.231	1.276	1.366	1.269	0.852	0.989	0.884	1.001	1.450	0.000	0.000	0.000
1976	0.029	1.054	0.967	0.948	0.874	1.057	1.209	0.914	1.204	2.005	0.900	0.000	0.000
1977	0.025	0.713	1.392	1.100	0.839	1.152	1.139	1.466	1.237	0.803	0.000	0.000	0.000
1978	0.229	0.341	1.012	1.112	1.251	0.619	0.728	0.385	1.805	0.840	1.612	0.000	0.000
1979	0.014	0.401	0.749	1.103	1.637	2.608	1.693	2.131	2.642	0.471	1.157	0.000	0.000
1980	0.015	0.247	0.801	0.803	0.932	1.499	0.660	0.953	0.492	0.000	0.000	0.000	0.000
1981	0.002	0.066	0.707	1.404	1.742	1.264	0.249	0.587	0.983	0.000	0.000	0.000	0.000
1982	0.111	0.489	0.820	1.237	1.774	0.628	0.643	0.711	0.000	0.000	0.000	0.000	0.000
1983	0.126	0.743	1.207	0.722	0.915	1.108	0.228	2.009	1.028	0.000	0.000	0.000	0.000
1984	0.054	0.629	1.411	1.946	2.457	1.529	2.774	2.345	0.000	0.000	0.000	0.000	0.000
1985	0.066	0.842	0.818	1.158	1.413	0.777	0.131	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.023	0.791	0.541	0.839	1.090	0.904	0.403	0.396	0.000	0.471	0.000	0.000	0.000
1987	0.019	0.749	1.258	1.404	1.539	0.859	1.879	2.408	2.545	0.000	0.000	0.000	0.000
1988	0.025	0.605	1.014	1.735	1.964	0.826	2.157	0.806	0.000	0.000	0.000	0.000	0.000
1989	0.022	0.143	0.477	0.905	1.371	0.908	1.609	0.099	0.000	0.000	0.000	0.000	0.000
1990	0.023	0.350	0.904	1.039	0.889	1.112	0.848	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.033	0.018	0.447	1.454	1.983	1.747	0.715	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.161	0.808	0.588	1.116	1.611	1.115	0.981	0.273	0.324	0.000	0.000	0.000	0.000
1993	0.540	0.131	0.802	1.405	1.200	1.161	0.535	0.339	0.000	0.000	0.000	0.000	0.000
1994	0.007	0.275	1.591	1.747	2.354	1.068	1.307	0.249	0.000	0.000	0.000	0.000	0.000
1995	0.006	0.032	0.484	1.248	1.089	0.438	0.865	1.019	0.683	0.000	0.000	0.000	0.000
1996	0.004	0.066	0.395	0.692	1.277	0.136	0.424	0.258	0.000	0.000	0.000	0.000	0.000
1997	0.004	0.075	0.251	0.819	0.845	0.661	2.037	1.689	0.767	0.000	0.000	0.000	0.000
1998	0.003	0.114	0.522	0.676	1.079	0.742	1.680	0.511	0.000	0.696	0.000	0.000	0.000
1999	0.002	0.222	0.431	0.596	0.530	0.795	0.393	0.138	0.468	0.000	0.000	0.000	0.000
2000	0.008	0.215	0.670	0.842	0.651	0.496	0.437	0.957	0.505	0.000	0.000	0.000	0.000
2001	0.012	0.221	0.859	0.795	0.832	0.504	0.874	0.456	0.697	0.000	0.000	0.000	0.000
2002	0.009	0.270	0.476	0.518	0.436	0.485	0.370	0.541	0.405	1.115	0.000	0.000	0.000
2003	0.038	0.166	0.544	0.583	0.430	0.396	0.944	0.596	0.794	1.746	0.388	0.000	0.000
2004	0.014	0.490	0.211	1.202	1.742	1.399	1.399	1.399	1.399	1.399	1.399	0.000	0.000

Table 14. Statistical properties of estimates for population abundance and survey calibration constants ($x10^3$) for Georges Bank yellowtail flounder for the Base VPA using Canadian ADAPT software.

Age	Estimate	Bootstrap Standard Error	Bootstrap Relative Error	Bootstrap Bias	Bootstrap Relative Bias
Population Abundance					
2	12168	5284	0.434	974.613	0.080
3	21649	7528	0.348	670.991	0.031
4	15294	5074	0.332	574.990	0.038
5	1613	588	0.365	76.108	0.047
Survey Calibration Constants					
DFO Survey: 1987-2005 (Age 2-6+)					
2	0.279	0.060	0.213	0.006	0.022
3	0.860	0.178	0.207	0.019	0.022
4	1.300	0.266	0.205	0.023	0.018
5	1.511	0.300	0.199	0.017	0.011
6	1.166	0.248	0.213	0.031	0.026
NMFS Spring Survey: Yankee 41, 1973-1981 (Age 1-6+)					
1	0.007	0.002	0.331	0.000	0.044
2	0.077	0.024	0.306	0.002	0.032
3	0.098	0.030	0.310	0.005	0.056
4	0.096	0.030	0.310	0.005	0.054
5	0.076	0.024	0.309	0.002	0.032
6	0.076	0.023	0.298	0.004	0.051
NMFS Spring Survey: Yankee 36, 1982-2005 (Age 1-6+)					
1	0.004	0.001	0.234	0.000	0.016
2	0.077	0.014	0.182	0.001	0.014
3	0.191	0.034	0.179	0.005	0.027
4	0.261	0.046	0.174	0.004	0.016
5	0.325	0.059	0.181	0.005	0.016
6	0.437	0.085	0.195	0.006	0.013
NMFS Fall Survey: 1973-2004 (Age 1-6+)					
1	0.045	0.007	0.159	0.001	0.018
2	0.106	0.016	0.153	0.001	0.013
3	0.219	0.034	0.156	0.004	0.016
4	0.240	0.037	0.152	0.001	0.006
5	0.299	0.050	0.166	0.003	0.010
6	0.367	0.072	0.197	0.006	0.016
Scallop: 1982-2004 (Age 1)					
1	0.030	0.006	0.186	0.000	0.014

Table 15. Statistical properties of estimates for population abundance and survey calibration constants ($x10^3$) for Georges Bank yellowtail flounder for the Major Change VPA using Canadian ADAPT software. (Survey series are split into 2 periods with a break after 1994):

		Bootstrap			
		Standard	Relative		Relative
Age	Estimate	Error	Error	Bias	Bias
	Population Abundance				
2	12572	2691	0.214	73	0.006
3	12606	1729	0.137	220	0.017
4	6589	1278	0.194	81	0.012
5	784	359	0.458	56	0.071
6	192	167	0.867	46	0.238
	Survey Calibration Constants				
DFO Survey: 1987-1994 (Age 2 to 5, 6-9)					
2	0.216	0.062	0.287	0.007	0.034
3	0.370	0.102	0.275	0.016	0.044
4	0.691	0.183	0.264	0.023	0.034
5	0.930	0.250	0.269	0.041	0.044
6-9	0.473	0.139	0.294	0.018	0.039
DFO Survey: 1995-2005 (Age 2 to 5, 6-9)					
2	1531.212	757.693	0.495	-39.302	-0.026
3	1832.756	619.026	0.338	-12.030	-0.007
4	2.337	0.526	0.225	0.070	0.030
5	2.576	0.624	0.242	0.117	0.045
6-9	1.921	0.444	0.231	0.048	0.025
NMFS Spring Survey: Yankee 41, 1973-1981 (Age 1 to 5,6-9)					
1	0.007	0.002	0.263	0.000	0.036
2	0.078	0.020	0.256	0.002	0.030
3	0.099	0.026	0.262	0.003	0.031
4	0.099	0.025	0.251	0.002	0.016
5	0.082	0.022	0.263	0.003	0.032
6-9	0.078	0.020	0.254	0.003	0.036
NMFS Spring Survey: Yankee 36, 1982-1994 (Age 1 to 5, 6-9)					
1	0.005	0.001	0.283	0.000	0.044
2	0.049	0.011	0.219	0.001	0.026
3	0.097	0.020	0.204	0.001	0.015
4	0.161	0.034	0.213	0.002	0.012
5	0.269	0.055	0.205	0.003	0.012
6-9	0.406	0.099	0.244	0.014	0.034
NMFS Spring Survey: Yankee 36, 1995-2005 (Age 1 to 5, 6-9)					
1	1707.919	1110.393	0.650	-59.064	-0.035
2	1462.626	749.504	0.512	-38.122	-0.026
3	634.290	615.668	0.971	9.428	0.015
4	0.537	0.116	0.217	0.018	0.033
5	0.529	0.122	0.231	0.016	0.030
6-9	0.432	0.099	0.228	0.011	0.024
NMFS Fall Survey: Yankee 36, 1982-1994 (Age 1 to 5, 6-9)					
1	0.042	0.007	0.168	0.001	0.013
2	0.092	0.015	0.158	0.001	0.010
3	0.167	0.026	0.158	0.003	0.016
4	0.198	0.031	0.158	0.002	0.011
5	0.300	0.053	0.175	0.005	0.015
6-9	0.328	0.068	0.208	0.008	0.024
NMFS Fall Survey: Yankee 36, 1995-2004 (Age 1 to 5, 6-9)					
1	3399.053	977.112	0.287	9.057	0.003
2	4458.297	888.561	0.199	-2.265	-0.001
3	2191.357	730.070	0.333	13.674	0.006
4	0.457	0.110	0.241	0.015	0.032
5	0.538	0.126	0.234	0.009	0.017
6-9	0.400	0.105	0.263	0.017	0.041
Scallop: 1982-1994 (Age 1)					
1	0.024	0.005	0.214	0.001	0.028
Scallop: 1995-2004 (Age 1)					
1	1280.278	971.511	0.759	1.589	0.001

Table 16. Beginning of year population abundance numbers (000's) for Georges Bank yellowtail flounder from the Base VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2005 from Canadian ADAPT software.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
1973	29386	24172	29516	17301	6967	3013	110355	80969	56797
1974	52186	23735	15136	12051	5733	2392	111234	59048	35312
1975	70632	40589	10932	5010	3078	1708	131951	61319	20729
1976	24731	53646	9853	2427	977	1562	93196	68465	14819
1977	17280	19675	15555	3172	720	851	57252	39972	20297
1978	54436	13807	7988	3391	957	374	80952	26515	12709
1979	25511	35603	8122	2468	1074	560	73337	47827	12223
1980	24034	20596	19711	3267	748	240	68595	44561	23965
1981	62999	19390	13269	7498	1302	221	104679	41680	22290
1982	22847	51482	14885	5537	1783	156	96691	73844	22361
1983	6582	16754	25939	5517	1515	345	56653	50071	33317
1984	10842	4755	6579	6473	2305	486	31441	20599	15844
1985	16748	8413	2089	1379	871	137	29637	12888	4475
1986	8473	12837	2990	767	402	223	25692	17219	4382
1987	9199	6775	4801	1439	281	201	22696	13497	6722
1988	22878	7390	2617	1153	309	72	34419	11541	4151
1989	9732	18280	3364	771	198	54	32399	22667	4387
1990	11542	7796	13006	1749	250	47	34390	22849	15052
1991	22787	9241	4485	4419	562	104	41598	18811	9570
1992	18342	18058	7433	2335	956	67	47190	28848	10790
1993	13961	12842	6613	3427	606	134	37582	23622	10779
1994	10668	6744	9265	2447	749	157	30031	19362	12618
1995	11144	8681	4234	1735	371	83	26247	15104	6423
1996	13218	9068	6897	2186	544	53	31966	18748	9680
1997	18549	10773	6913	3921	949	230	41334	22786	12013
1998	24142	15132	8148	4309	1579	349	53660	29518	14386
1999	26086	19708	11040	3786	1625	472	62717	36631	16924
2000	22328	21324	12811	5826	1554	784	64627	42299	20975
2001	25862	18141	14003	5145	1991	1057	66199	40337	22196
2002	37965	20917	12093	4679	1699	1154	78508	40543	19626
2003	33271	30852	13135	6444	2180	1933	87815	54544	23692
2004	13757	27095	21819	6308	3218	2355	74552	60795	33700
2005	20972	11193	20978	14719	1536	1357	70756	49784	38590

Table 17. Beginning of year population abundance numbers (000's) for Georges Bank yellowtail flounder from the Major Change VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2005 from Canadian ADAPT software.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1973	29579	24354	29811	17112	6142	2379	515	182	26	6	2	1	1
1974	51857	23892	15285	12291	5581	1645	804	170	100	2	2	1	1
1975	70056	40320	11060	5131	3270	1343	565	245	45	19	1	1	1
1976	24460	53174	9639	2529	1072	752	469	172	83	14	4	1	1
1977	16851	19452	15175	2999	802	366	214	115	56	20	1	1	1
1978	53583	13455	7807	3090	817	284	95	56	22	13	7	1	1
1979	24860	34905	7835	2323	832	192	125	37	31	3	5	1	1
1980	23543	20064	19141	3033	631	132	12	19	4	2	1	1	1
1981	62671	18989	12834	7037	1112	203	24	5	6	2	1	1	1
1982	22681	51213	14557	5183	1415	159	47	15	2	2	1	1	1
1983	6540	16619	25719	5251	1232	197	70	20	6	2	1	1	1
1984	10781	4721	6470	6298	2089	404	53	45	2	2	1	1	1
1985	16655	8363	2061	1292	737	147	72	3	4	2	1	1	1
1986	8493	12760	2950	745	332	147	55	51	2	3	1	1	1
1987	9001	6792	4739	1406	264	91	49	30	28	2	1	1	1
1988	22539	7228	2630	1103	283	46	32	6	2	2	1	1	1
1989	9803	18003	3232	782	159	32	17	3	2	2	1	1	1
1990	11354	7855	12779	1642	259	33	11	3	2	2	1	1	1
1991	22724	9083	4532	4238	476	87	9	4	2	2	1	1	1
1992	17886	18006	7307	2373	811	54	12	4	3	2	1	1	1
1993	13722	12469	6570	3324	636	133	14	4	2	2	1	1	1
1994	10001	6549	8960	2413	668	157	34	7	2	2	1	1	1
1995	11907	8135	4074	1495	344	52	44	8	4	2	1	1	1
1996	13937	9693	6450	2056	351	95	27	15	2	2	1	1	1
1997	18748	11362	7425	3555	843	80	68	15	10	2	1	1	1
1998	24760	15295	8630	4728	1282	297	34	7	2	4	1	1	1
1999	26245	20214	11174	4179	1965	356	116	5	4	2	1	1	1
2000	20497	21454	13225	5936	1873	944	131	64	4	2	1	1	1
2001	23987	16642	14109	5482	2080	790	468	69	20	2	1	1	1
2002	22976	19383	10867	4766	1971	729	384	157	36	8	1	1	1
2003	20451	18580	11880	5443	2251	1013	361	213	73	19	2	1	1
2004	15352	16600	11777	5286	2402	1146	535	107	91	25	2	1	1
2005	18612	12499	12386	6509	728	147	131	61	12	10	3	0	1

Table 18. Fishing mortality rate for Georges Bank yellowtail from the Base VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2004 from Canadian ADAPT software.

Year	Age group						
	1	2	3	4	5	6	3+
1973	0.014	0.268	0.696	0.905	0.905	0.905	0.796
1974	0.051	0.575	0.906	1.165	1.165	1.165	1.054
1975	0.075	1.216	1.305	1.435	1.435	1.435	1.366
1976	0.029	1.038	0.933	1.015	1.015	1.015	0.961
1977	0.024	0.701	1.323	0.999	0.999	0.999	1.248
1978	0.225	0.331	0.975	0.950	0.950	0.950	0.965
1979	0.014	0.391	0.711	0.994	0.994	0.994	0.806
1980	0.015	0.240	0.766	0.720	0.720	0.720	0.758
1981	0.002	0.064	0.674	1.237	1.237	1.237	0.902
1982	0.110	0.485	0.792	1.096	1.096	1.096	0.894
1983	0.125	0.735	1.188	0.673	0.673	0.673	1.074
1984	0.054	0.623	1.363	1.805	1.805	1.805	1.622
1985	0.066	0.834	0.802	1.032	1.032	1.032	0.925
1986	0.024	0.784	0.531	0.804	0.804	0.804	0.618
1987	0.019	0.751	1.227	1.338	1.338	1.338	1.259
1988	0.024	0.587	1.022	1.561	1.561	1.561	1.221
1989	0.022	0.140	0.454	0.925	0.925	0.925	0.564
1990	0.022	0.353	0.879	0.935	0.935	0.935	0.887
1991	0.033	0.018	0.453	1.331	1.331	1.331	0.920
1992	0.156	0.805	0.574	1.150	1.150	1.150	0.753
1993	0.528	0.127	0.794	1.321	1.321	1.321	0.998
1994	0.006	0.266	1.475	1.686	1.686	1.686	1.531
1995	0.006	0.030	0.461	0.960	0.960	0.960	0.631
1996	0.005	0.071	0.365	0.635	0.635	0.635	0.442
1997	0.004	0.079	0.273	0.709	0.709	0.709	0.458
1998	0.003	0.115	0.567	0.775	0.775	0.775	0.657
1999	0.002	0.231	0.439	0.691	0.691	0.691	0.527
2000	0.008	0.221	0.712	0.873	0.873	0.873	0.776
2001	0.012	0.205	0.895	0.907	0.907	0.907	0.902
2002	0.007	0.264	0.428	0.562	0.562	0.562	0.482
2003	0.005	0.137	0.529	0.491	0.491	0.491	0.515
2004	0.005	0.050	0.176	1.158	1.158	1.158	0.557

Table 19. Fishing mortality rate for Georges Bank yellowtail from the Major Change VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2004 from Canadian ADAPT software.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1973	0.013	0.266	0.686	0.920	1.117	0.885	0.909	0.402	2.469	1.123	0.163	0.000	0.000
1974	0.052	0.570	0.892	1.124	1.224	0.868	0.987	1.131	1.453	0.000	0.138	0.166	0.000
1975	0.076	1.231	1.276	1.366	1.269	0.852	0.989	0.884	1.001	1.450	0.000	0.000	0.000
1976	0.029	1.054	0.967	0.948	0.874	1.057	1.209	0.914	1.204	2.005	0.900	0.000	0.000
1977	0.025	0.713	1.392	1.100	0.839	1.152	1.139	1.466	1.237	0.803	0.000	0.000	0.000
1978	0.229	0.341	1.012	1.112	1.251	0.619	0.728	0.385	1.805	0.840	1.612	0.000	0.000
1979	0.014	0.401	0.749	1.103	1.637	2.608	1.693	2.131	2.642	0.471	1.157	0.000	0.000
1980	0.015	0.247	0.801	0.803	0.932	1.499	0.660	0.953	0.492	0.000	0.000	0.000	0.000
1981	0.002	0.066	0.707	1.404	1.742	1.264	0.249	0.587	0.983	0.000	0.000	0.000	0.000
1982	0.111	0.489	0.820	1.237	1.774	0.628	0.643	0.711	0.000	0.000	0.000	0.000	0.000
1983	0.126	0.743	1.207	0.722	0.915	1.108	0.228	2.009	1.028	0.000	0.000	0.000	0.000
1984	0.054	0.629	1.411	1.946	2.457	1.529	2.774	2.345	0.000	0.000	0.000	0.000	0.000
1985	0.066	0.842	0.818	1.158	1.413	0.777	0.131	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.023	0.791	0.541	0.839	1.090	0.904	0.403	0.396	0.000	0.471	0.000	0.000	0.000
1987	0.019	0.749	1.258	1.404	1.539	0.859	1.879	2.408	2.545	0.000	0.000	0.000	0.000
1988	0.025	0.605	1.014	1.735	1.964	0.826	2.157	0.806	0.000	0.000	0.000	0.000	0.000
1989	0.022	0.143	0.477	0.905	1.371	0.908	1.609	0.099	0.000	0.000	0.000	0.000	0.000
1990	0.023	0.350	0.904	1.039	0.889	1.112	0.848	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.033	0.018	0.447	1.454	1.983	1.747	0.715	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.161	0.808	0.588	1.116	1.611	1.115	0.981	0.273	0.324	0.000	0.000	0.000	0.000
1993	0.540	0.131	0.802	1.405	1.200	1.161	0.535	0.339	0.000	0.000	0.000	0.000	0.000
1994	0.007	0.275	1.591	1.747	2.354	1.068	1.307	0.249	0.000	0.000	0.000	0.000	0.000
1995	0.006	0.032	0.484	1.248	1.089	0.438	0.865	1.019	0.683	0.000	0.000	0.000	0.000
1996	0.004	0.066	0.396	0.692	1.277	0.136	0.424	0.258	0.000	0.000	0.000	0.000	0.000
1997	0.004	0.075	0.251	0.820	0.845	0.661	2.037	1.689	0.767	0.000	0.000	0.000	0.000
1998	0.003	0.114	0.525	0.678	1.081	0.742	1.680	0.511	0.000	0.696	0.000	0.000	0.000
1999	0.002	0.224	0.433	0.602	0.533	0.798	0.393	0.138	0.468	0.000	0.000	0.000	0.000
2000	0.008	0.219	0.681	0.849	0.663	0.501	0.440	0.957	0.505	0.000	0.000	0.000	0.000
2001	0.013	0.226	0.885	0.823	0.848	0.521	0.892	0.461	0.697	0.000	0.000	0.000	0.000
2002	0.012	0.289	0.491	0.550	0.465	0.503	0.390	0.563	0.412	1.115	0.000	0.000	0.000
2003	0.009	0.252	0.607	0.615	0.474	0.437	1.019	0.652	0.862	1.846	0.388	0.000	0.000
2004	-0.002	0.091	0.383	1.683	2.283	1.899	1.899	1.899	1.899	1.899	1.899	0.000	0.000

Table 20. Beginning of year weight (kg) at age for Georges Bank yellowtail. The 2005 value is the average for 2000-2004.

	Age												
Year	1	2	3	4	5	6	7	8	9	10	11	12	6+
1973	0.010	0.230	0.401	0.493	0.564	0.645	0.856	1.096	1.100	1.300	1.400	1.500	0.704
1974	0.010	0.230	0.415	0.530	0.598	0.660	0.790	1.150	1.100	1.300	1.400	1.500	0.755
1975	0.010	0.230	0.410	0.524	0.613	0.684	0.707	0.769	1.100	1.300	1.400	1.500	0.715
1976	0.010	0.230	0.415	0.557	0.642	0.709	0.768	0.780	1.100	1.300	1.400	1.500	0.767
1977	0.010	0.230	0.404	0.587	0.704	0.800	0.913	0.928	1.100	1.300	1.400	1.500	0.885
1978	0.010	0.230	0.418	0.601	0.713	0.839	0.902	1.017	1.100	1.300	1.400	1.500	0.918
1979	0.010	0.230	0.381	0.578	0.713	0.823	0.948	0.926	1.100	1.300	1.400	1.500	0.900
1980	0.010	0.230	0.403	0.551	0.732	0.878	1.010	1.095	1.100	1.300	1.400	1.500	0.907
1981	0.010	0.230	0.397	0.546	0.681	0.818	0.940	1.390	1.100	1.300	1.400	1.500	0.837
1982	0.010	0.230	0.403	0.564	0.675	0.868	0.923	1.072	1.100	1.300	1.400	1.500	0.895
1983	0.010	0.230	0.364	0.543	0.694	0.853	1.035	1.163	1.100	1.300	1.400	1.500	0.907
1984	0.010	0.230	0.335	0.470	0.627	0.741	0.954	1.018	1.100	1.300	1.400	1.500	0.796
1985	0.010	0.230	0.347	0.493	0.604	0.723	0.735	1.019	1.100	1.300	1.400	1.500	0.724
1986	0.010	0.230	0.442	0.583	0.740	0.844	0.876	0.954	1.100	1.300	1.400	1.500	0.867
1987	0.010	0.230	0.423	0.606	0.727	0.921	0.904	0.856	1.100	1.300	1.400	1.500	0.936
1988	0.010	0.230	0.425	0.604	0.758	0.904	0.927	1.077	1.100	1.300	1.400	1.500	0.925
1989	0.010	0.230	0.413	0.633	0.776	0.905	1.105	0.988	1.100	1.300	1.400	1.500	0.987
1990	0.010	0.230	0.359	0.552	0.706	0.826	1.013	1.135	1.100	1.300	1.400	1.500	0.866
1991	0.010	0.230	0.327	0.438	0.650	0.767	1.014	1.078	1.100	1.300	1.400	1.500	0.782
1992	0.010	0.230	0.294	0.441	0.562	0.891	0.978	1.304	1.100	1.300	1.400	1.500	0.917
1993	0.010	0.230	0.333	0.428	0.545	0.741	1.114	1.084	1.100	1.300	1.400	1.500	0.767
1994	0.010	0.230	0.315	0.422	0.557	0.676	0.781	1.192	1.100	1.300	1.400	1.500	0.702
1995	0.010	0.230	0.300	0.401	0.523	0.689	0.807	0.620	1.100	1.300	1.400	1.500	0.760
1996	0.010	0.230	0.318	0.445	0.578	0.731	0.902	1.018	1.100	1.300	1.400	1.500	0.836
1997	0.010	0.230	0.351	0.470	0.623	0.777	0.897	1.121	1.100	1.300	1.400	1.500	0.889
1998	0.010	0.230	0.378	0.478	0.609	0.789	0.883	1.024	1.100	1.300	1.400	1.500	0.812
1999	0.010	0.230	0.404	0.534	0.641	0.788	0.964	1.181	1.100	1.300	1.400	1.500	0.819
2000	0.010	0.230	0.421	0.555	0.697	0.832	0.958	1.013	1.100	1.300	1.400	1.500	0.861
2001	0.010	0.230	0.416	0.548	0.704	0.879	0.967	1.139	1.100	1.300	1.400	1.500	0.932
2002	0.010	0.230	0.410	0.552	0.719	0.891	1.037	1.145	1.100	1.300	1.400	1.500	0.972
2003	0.010	0.230	0.427	0.565	0.745	0.885	1.008	1.104	1.100	1.300	1.400	1.500	0.974
2004	0.010	0.230	0.396	0.526	0.687	0.857	0.973	1.116	1.100	1.300	1.400	1.500	0.922
2005	0.010	0.230	0.414	0.549	0.710	0.869	0.989	1.103	1.100	1.300	1.400	1.500	0.932

Table 21. Beginning of year biomass (t) for Georges Bank yellowtail from the Base VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2005 from Canadian ADAPT software.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
1973	294	5559	11835	8537	3928	2122	32275	31981	26422
1974	522	5459	6288	6382	3427	1806	23884	23362	17903
1975	706	9336	4484	2626	1887	1222	20261	19555	10219
1976	247	12339	4085	1352	627	1199	19850	19602	7264
1977	173	4525	6289	1862	507	753	14108	13935	9410
1978	544	3176	3336	2039	682	343	10119	9575	6400
1979	255	8189	3093	1427	765	504	14234	13979	5790
1980	240	4737	7938	1798	547	218	15479	15239	10501
1981	630	4460	5265	4092	886	185	15518	14888	10429
1982	228	11841	6000	3122	1203	140	22534	22305	10465
1983	66	3854	9450	2994	1051	313	17727	17662	13808
1984	108	1094	2204	3040	1445	387	8277	8169	7075
1985	167	1935	726	680	526	99	4133	3966	2031
1986	85	2953	1320	447	298	193	5296	5211	2259
1987	92	1558	2029	872	204	188	4944	4852	3294
1988	229	1700	1112	696	234	67	4037	3809	2109
1989	97	4204	1389	488	154	53	6386	6289	2085
1990	115	1793	4674	965	177	40	7765	7649	5856
1991	228	2125	1467	1936	366	81	6204	5976	3850
1992	183	4153	2186	1029	538	61	8150	7967	3814
1993	140	2954	2204	1466	330	103	7195	7056	4102
1994	107	1551	2918	1032	417	110	6135	6028	4477
1995	111	1997	1268	696	194	63	4330	4219	2222
1996	132	2086	2196	973	314	45	5745	5613	3528
1997	185	2478	2424	1844	591	204	7727	7542	5064
1998	241	3480	3077	2060	961	284	10104	9863	6382
1999	261	4533	4464	2022	1041	387	12707	12446	7914
2000	223	4905	5397	3235	1083	675	15519	15295	10391
2001	259	4172	5821	2819	1402	984	15457	15199	11026
2002	380	4811	4953	2583	1222	1121	15070	14690	9879
2003	333	7096	5607	3639	1623	1884	20181	19848	12752
2004	138	6232	8644	3321	2209	2171	22715	22577	16345
2005	210	2574	8619	8061	1101	1297	21863	21653	19079

Table 22. Beginning of year biomass (t) for Georges Bank yellowtail from the Major Change VPA formulation using the bootstrap bias adjusted population abundance at the beginning of 2005 from Canadian ADAPT software.

	Age														
Year	1	2	3	4	5	6	7	8	9	10	11	12	1+	2+	3+
1973	296	5601	11953	8444	3463	1534	441	200	29	8	3	2	31974	31678	26077
1974	519	5495	6350	6509	3336	1086	635	196	110	2	2	2	24242	23724	18228
1975	701	9274	4536	2690	2005	919	400	189	49	25	2	2	20790	20089	10815
1976	245	12230	3996	1409	688	534	360	134	91	18	5	2	19712	19468	7237
1977	169	4474	6136	1760	565	293	196	106	62	26	2	2	13791	13622	9148
1978	536	3095	3260	1858	583	238	85	57	24	17	10	2	9766	9230	6135
1979	249	8028	2984	1343	593	158	119	35	34	4	7	2	13555	13306	5278
1980	235	4615	7709	1670	462	116	12	21	4	2	2	2	14849	14614	9999
1981	627	4367	5092	3840	757	167	23	7	7	2	2	2	14893	14266	9899
1982	227	11779	5868	2922	955	138	43	17	2	2	2	2	21958	21731	9952
1983	65	3822	9370	2849	855	168	72	24	7	2	2	2	17238	17173	13351
1984	108	1086	2167	2957	1309	300	51	46	2	2	2	2	8032	7924	6839
1985	167	1923	716	637	445	106	53	3	4	2	2	2	4060	3893	1970
1986	85	2935	1303	435	246	124	48	49	2	4	2	2	5235	5150	2215
1987	90	1562	2003	852	192	84	44	26	31	2	2	2	4890	4800	3238
1988	225	1662	1117	666	214	42	29	7	2	2	2	2	3972	3747	2084
1989	98	4141	1335	495	124	29	18	3	2	2	2	2	6252	6154	2013
1990	114	1807	4593	906	183	27	11	3	2	2	2	2	7651	7538	5731
1991	227	2090	1482	1856	309	67	9	4	2	2	2	2	6054	5827	3736
1992	179	4141	2149	1046	456	48	12	5	3	2	2	2	8045	7866	3725
1993	137	2868	2189	1422	347	98	16	4	2	2	2	2	7090	6953	4085
1994	100	1506	2822	1017	372	106	27	8	2	2	2	2	5967	5867	4361
1995	119	1871	1221	600	180	36	36	5	5	2	2	2	4078	3959	2088
1996	139	2229	2053	915	203	69	25	15	2	2	2	2	5658	5519	3290
1997	187	2613	2603	1672	525	62	61	16	11	2	2	2	7758	7571	4958
1998	248	3518	3259	2261	781	234	30	7	2	5	2	2	10348	10100	6583
1999	262	4649	4518	2231	1259	281	111	6	4	2	2	2	13328	13066	8417
2000	205	4934	5572	3296	1306	785	126	65	4	2	2	2	16299	16094	11159
2001	240	3828	5865	3003	1464	694	453	79	22	2	2	2	15654	15414	11587
2002	230	4458	4450	2630	1418	650	396	180	39	11	2	2	14468	14238	9780
2003	205	4273	5071	3073	1676	897	364	235	81	25	3	2	15905	15700	11427
2004	154	3818	4666	2783	1649	981	521	119	100	33	3	2	14828	14675	10857
2005	186	2875	5127	3575	517	127	130	68	13	13	4	0	12635	12449	9575

Table 23. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2006 at F_{Ref} using the bootstrap bias adjusted population abundance at the beginning of 2005 from the Base VPA formulation.

Projected Population Numbers **Age**

	1	2	3	4	5	6+
2005.00	20972	11193	20978	14719	1536	1357
2006.00	20972	17110	8258	13217	8123	1597
2007.00	20972	17132	13113	5727	8428	6197

Fishing Mortality

	1	2	3	4	5	6+
2005.00	0.004	0.104	0.262	0.395	0.395	0.395
2006.00	0.002	0.066	0.166	0.250	0.250	0.250

Partial Recruitment

	1	2	3	4	5	6
2005.00	0.01	0.26	0.66	1.00	1.00	1.00
2006.00	0.01	0.26	0.66	1.00	1.00	1.00

Weight at Beginning of Year for Population

	1	2	3	4	5	6
2005.00	0.01	0.23	0.41	0.55	0.72	0.96
2006.00	0.01	0.23	0.41	0.55	0.72	0.96
2007.00	0.01	0.23	0.41	0.55	0.72	0.96

Beginning of yea Projected Population Biomass (t)

	1	2	3	4	5	6	1+	2+	3+	4+
2005.00	210	2574	8622	8066	1101	1297	21871	21661	19087	10465
2006.00	210	3935	3394	7243	5824	1526	22132	21922	17987	14593
2007.00	210	3940	5390	3138	6043	5925	24645	24435	20495	15105

Projected Catch Numbers

	1	2	3	4	5	6
2005.00	67	1005	4401	4377	457	404
2006.00	43	992	1148	2661	1635	321

Average Weight for Catch (kg)

	1	2	3	4	5	6
2005.00	0.23	0.34	0.47	0.63	0.79	1.10
2006.00	0.23	0.34	0.47	0.63	0.79	1.10

Projected Catch Biomass (t)

	1	2	3	4	5	6	1+	2+	3+	4+
2005.00	15	346	2055	2775	363	446	6000	5985	5639	3584
2006.00	10	341	536	1687	1298	355	4227	4217	3876	3340

Table 24. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2006 at F_{Ref} using the bootstrap bias adjusted population abundance at the beginning of 2005 from the Major Change VPA formulation.

Projected Population Numbers

	Age												
	1	2	3	4	5	6	7	8	9	10	11	12	13
2005.00	18612	12499	12386	6509	728	147	131	61	12	10	3	0	1
2006.00	18612	15065	7710	5575	2356	264	53	47	22	4	4	1	0
2007.00	18612	15185	11309	5255	3555	1502	168	34	30	14	3	2	1

Fishing Mortality

	1	2	3	4	5	6	7	8	9	10	11	12	13
2005.00	0.011	0.283	0.598	0.816	0.816	0.816	0.816	0.816	0.816	0.816	0.816	0.816	0.816
2006.00	0.004	0.087	0.183	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250

Partial Recruitment

1	2	3	4	5	6	7	8	9	10	11	12	13
0.01	0.35	0.73	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Weight at Beginning of year for Population (kg)

1	2	3	4	5	6	7	8	9	10	11	12	13
0.01	0.23	0.41	0.55	0.72	0.88	1.01	1.12	1.10	1.30	1.40	1.50	1.50

Beginning of Year Projected Population Biomass (t)

	1	2	3	4	5	6	7	8	9	10	11	12	13	1+	2+	3+	4+
2005.00	186	2875	5091	3567	522	129	132	69	13	13	4	0	2	12602	12416	9542	4451
2006.00	186	3465	3169	3055	1689	231	53	53	24	6	5	2	0	11940	11754	8289	5120
2007.00	186	3493	4648	2880	2549	1319	169	38	33	18	4	4	1	15342	15156	11663	7015

Projected Catch Numbers

	1	2	3	4	5	6	7	8	9	10	11	12	13
2005.00	192	2807	5104	3335	373	75	67	31	6	5	1	0	1
2006.00	59	1136	1174	1122	474	53	11	10	4	1	1	0	0

Average Weight for Catch (kg)

1	2	3	4	5	6	7	8	9	10	11	12	13
0.23	0.34	0.47	0.63	0.79	0.94	1.03	1.21	1.29	1.39	1.56	1.56	1.56

Projected Catch Biomass (t)

	1	2	3	4	5	6	7	8	9	10	11	12	13	1+	2+	3+	4+
2005.00	44	966	2384	2114	296	70	69	38	8	7	2	0	1	6000	5956	4991	2607
2006.00	13	391	548	712	377	50	11	12	6	1	1	0	0	2121	2108	1717	1169

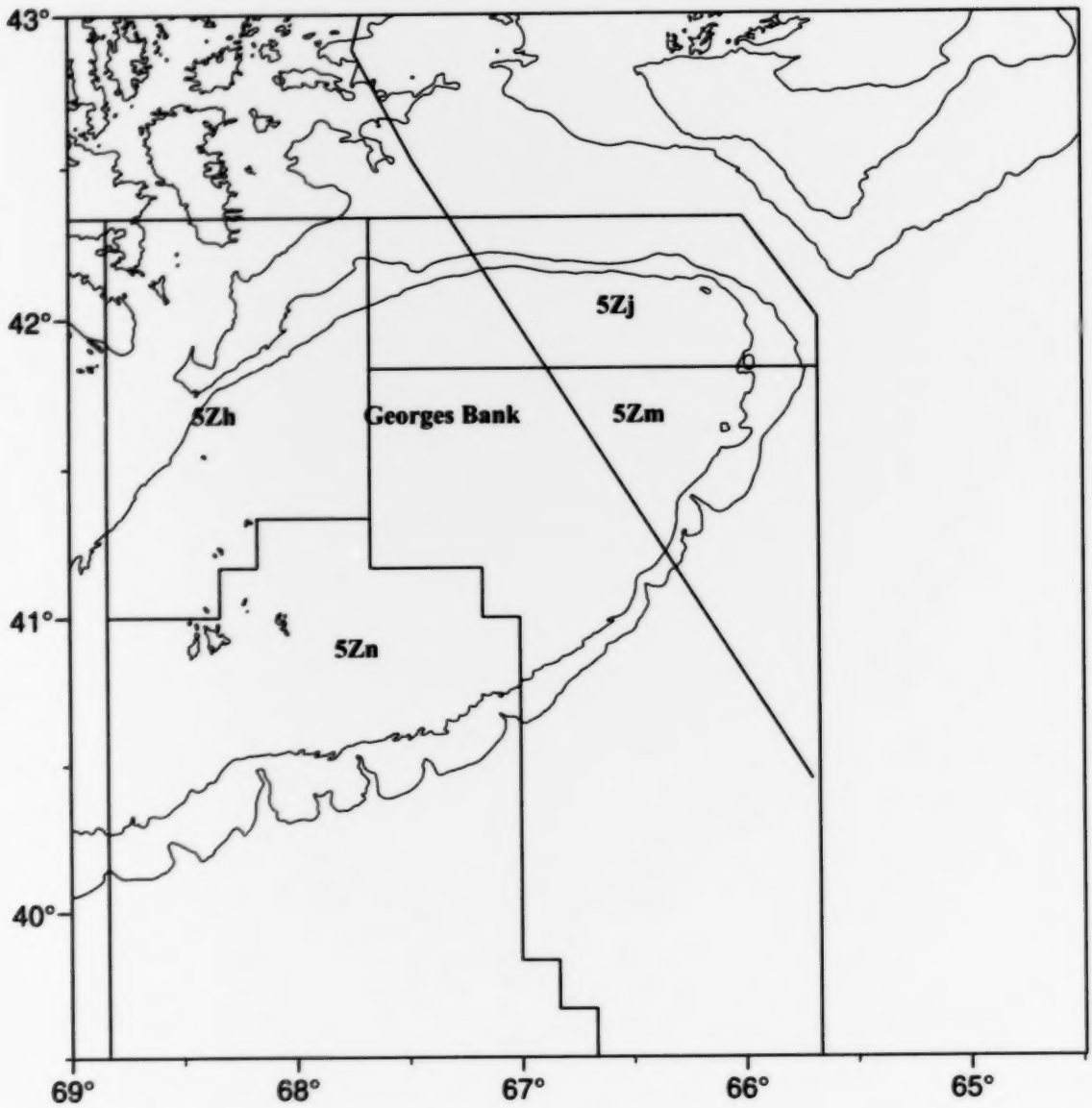

Fig. 1a. Location of statistical unit areas for Canadian fisheries in NAFO Subdivision 5Ze.

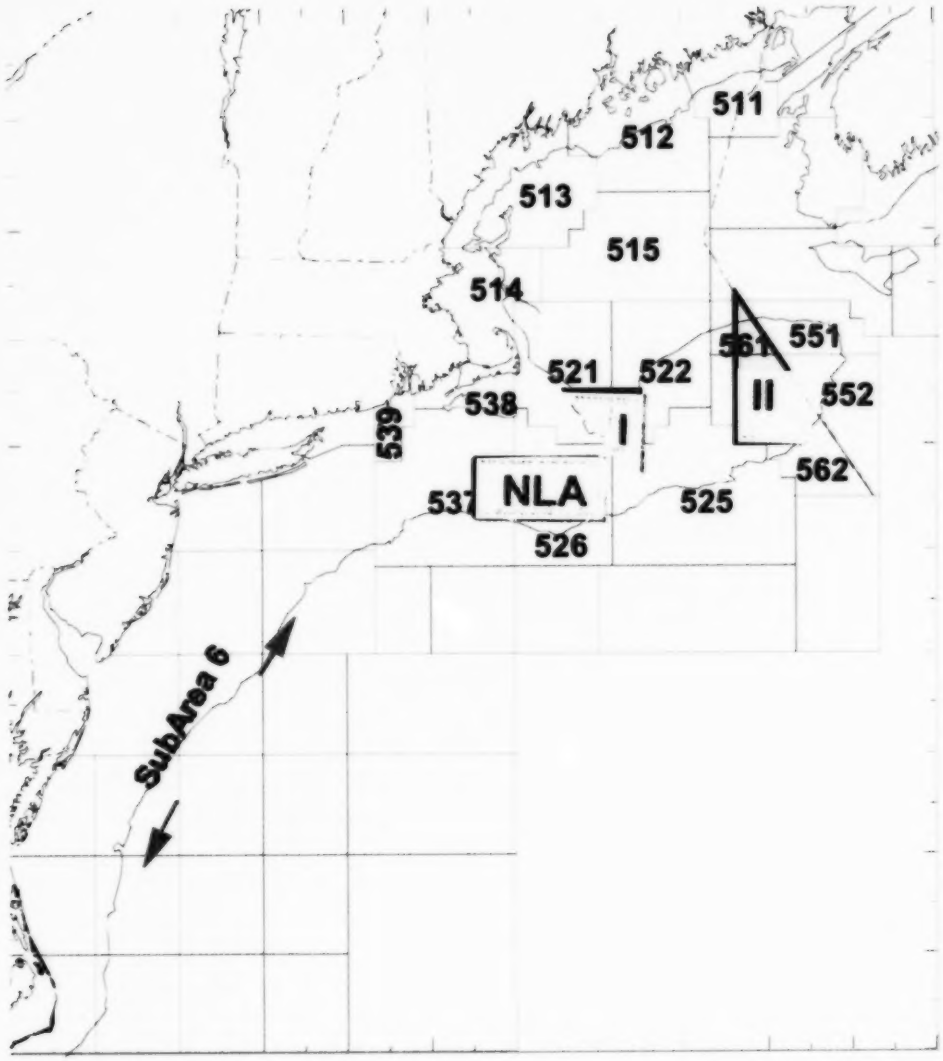

Fig. 1b. Statistical areas used for monitoring northeast U.S. fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas have been closed to fishing year-round since 1994, with exceptions.

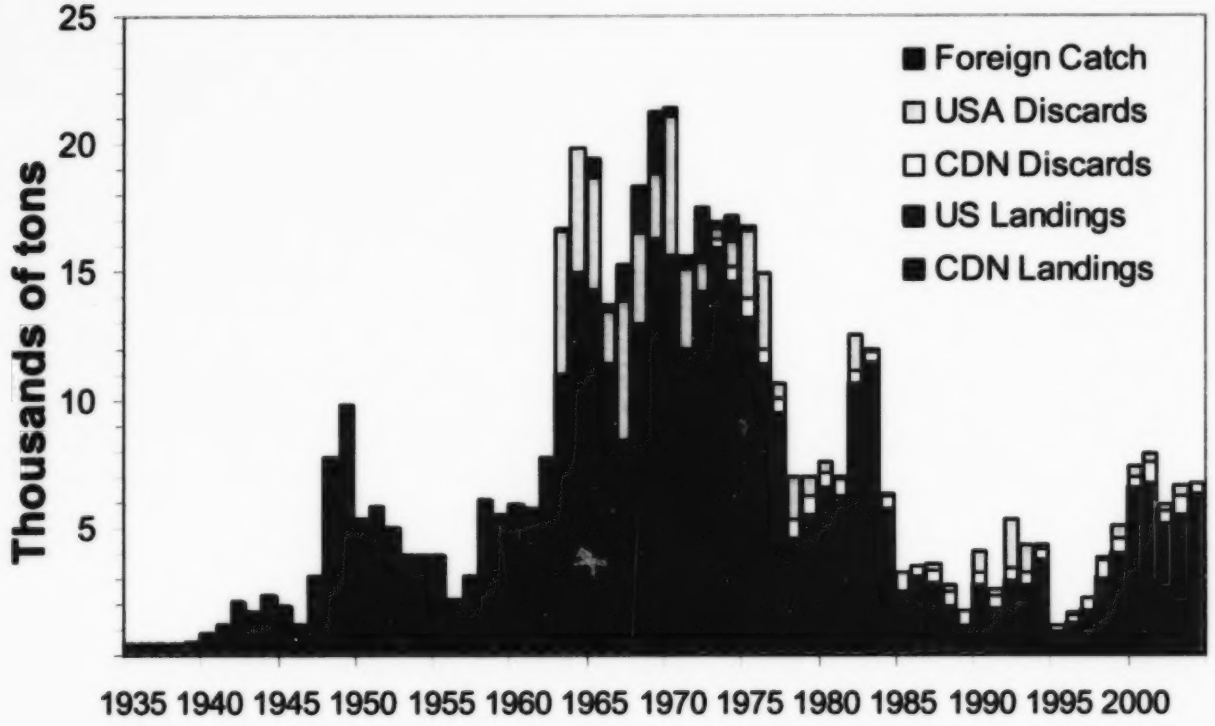

Fig. 2. Landings (including discards) of Georges Bank yellowtail flounder by nation, 1935-2004.

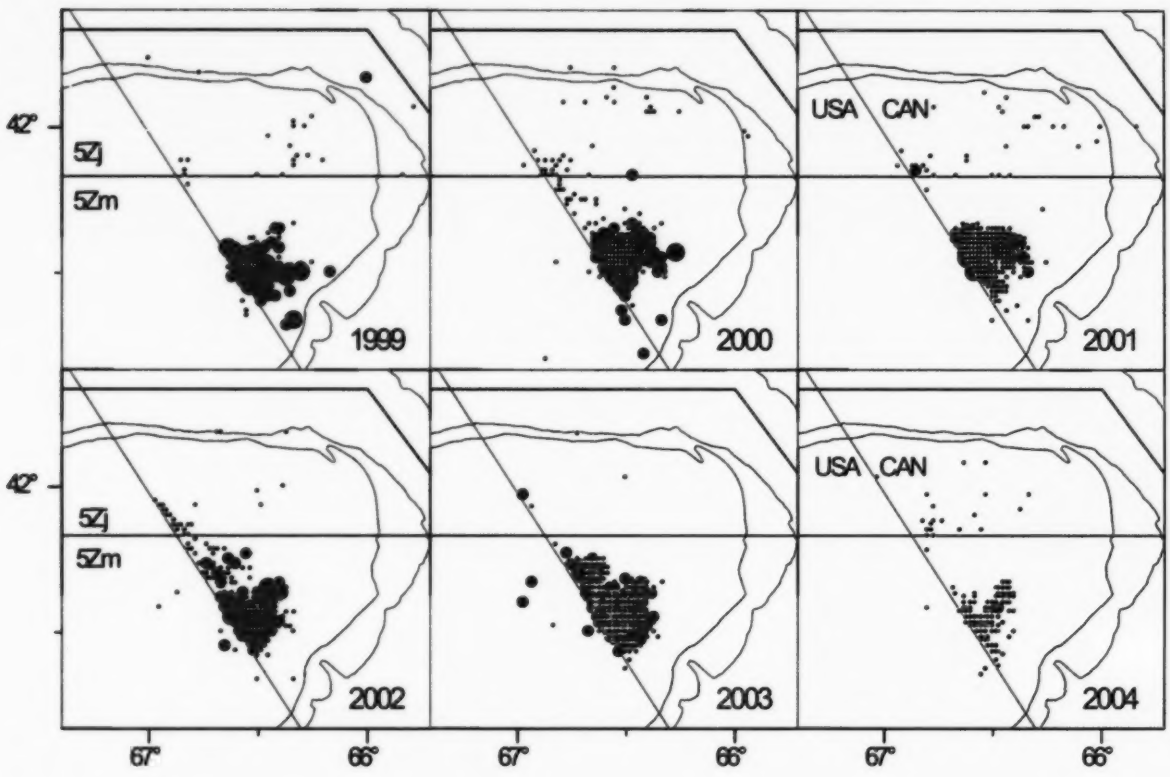

Fig 3. Distribution of Canadian mobile gear (TC 1-3) yellowtail flounder catches from commercial landings data for 1999-2003 where trip landings were greater than 0.5t. For 2004, catches > .100 t are shown. Expanding symbols represent metric tonnes.

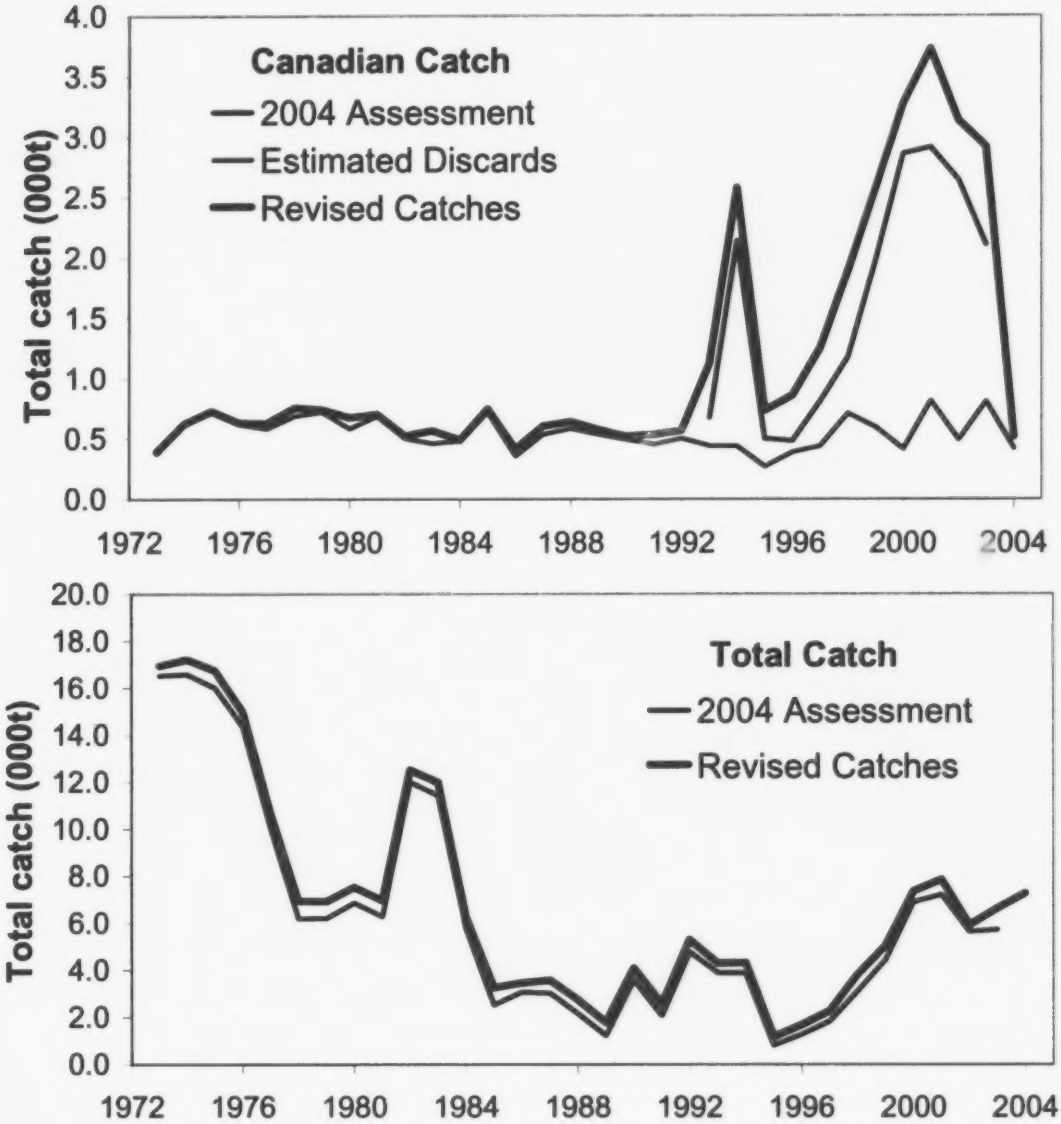

Figure 4. Canadian catch used in the 2004 assessment and revised Canadian catch which includes bycatch from the offshore scallop fishery (upper panel) to 2004, and total catch used in the VPA for the 2004 assessment and revised total catch used in the 2005 assessment.

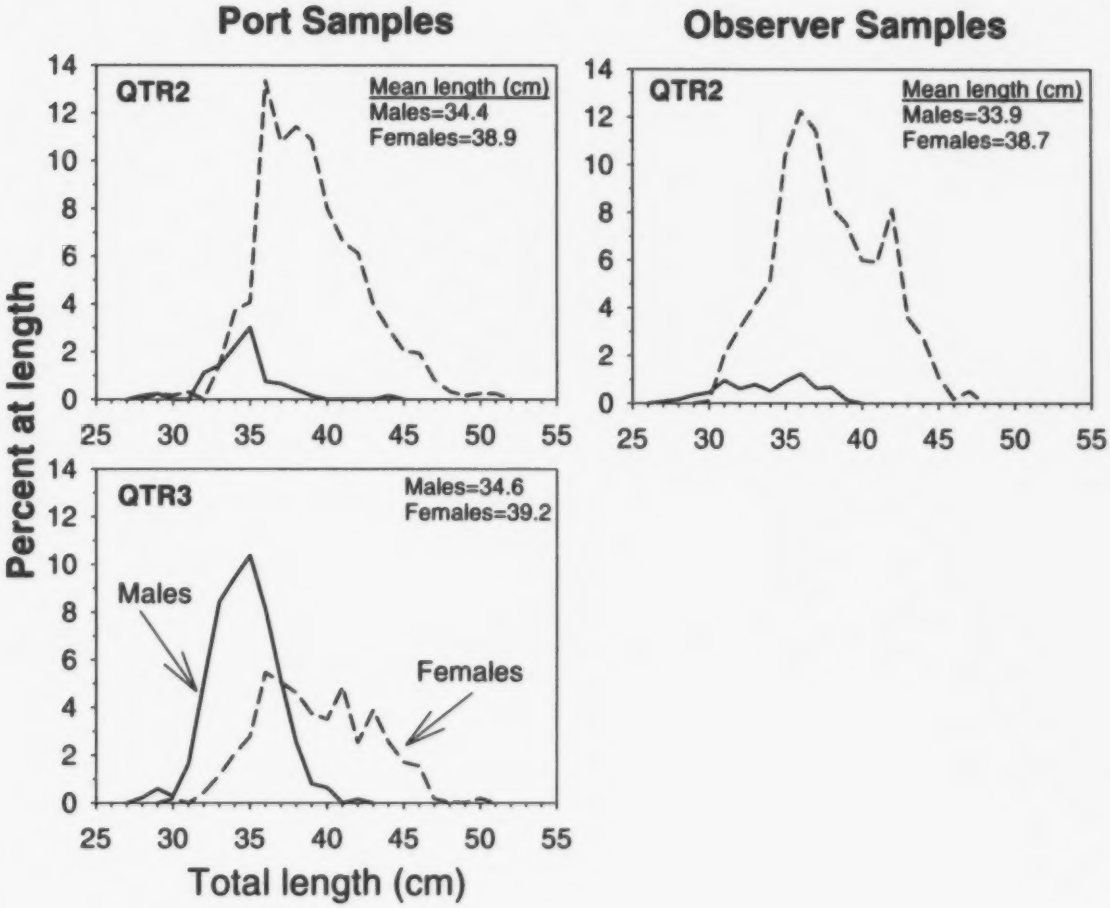

Fig. 5. Length frequencies of Georges Bank yellowtail flounder caught in the 2004 Canadian fishery sampled by sex at dockside (left panels) and at sea (right panel) during the same quarter.

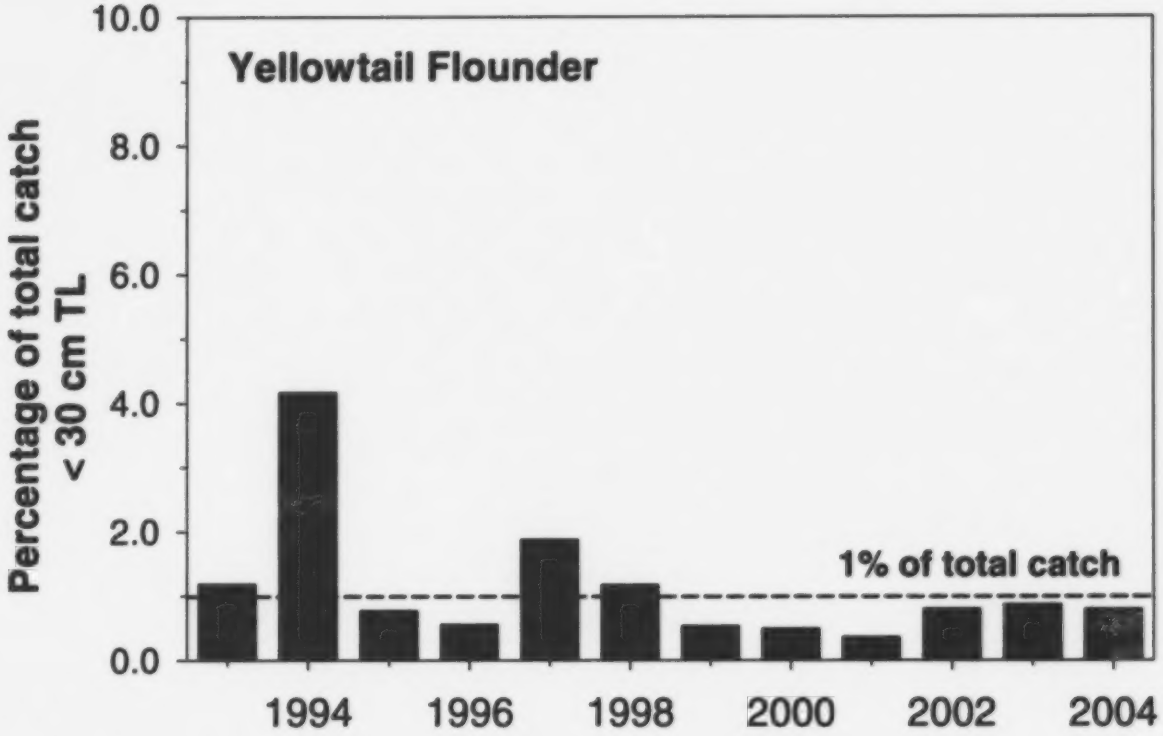

Fig. 6. Percentage of total catch of Georges Bank yellowtail flounder less than 30 cm total length from the Canadian fishery, 1993-2004.

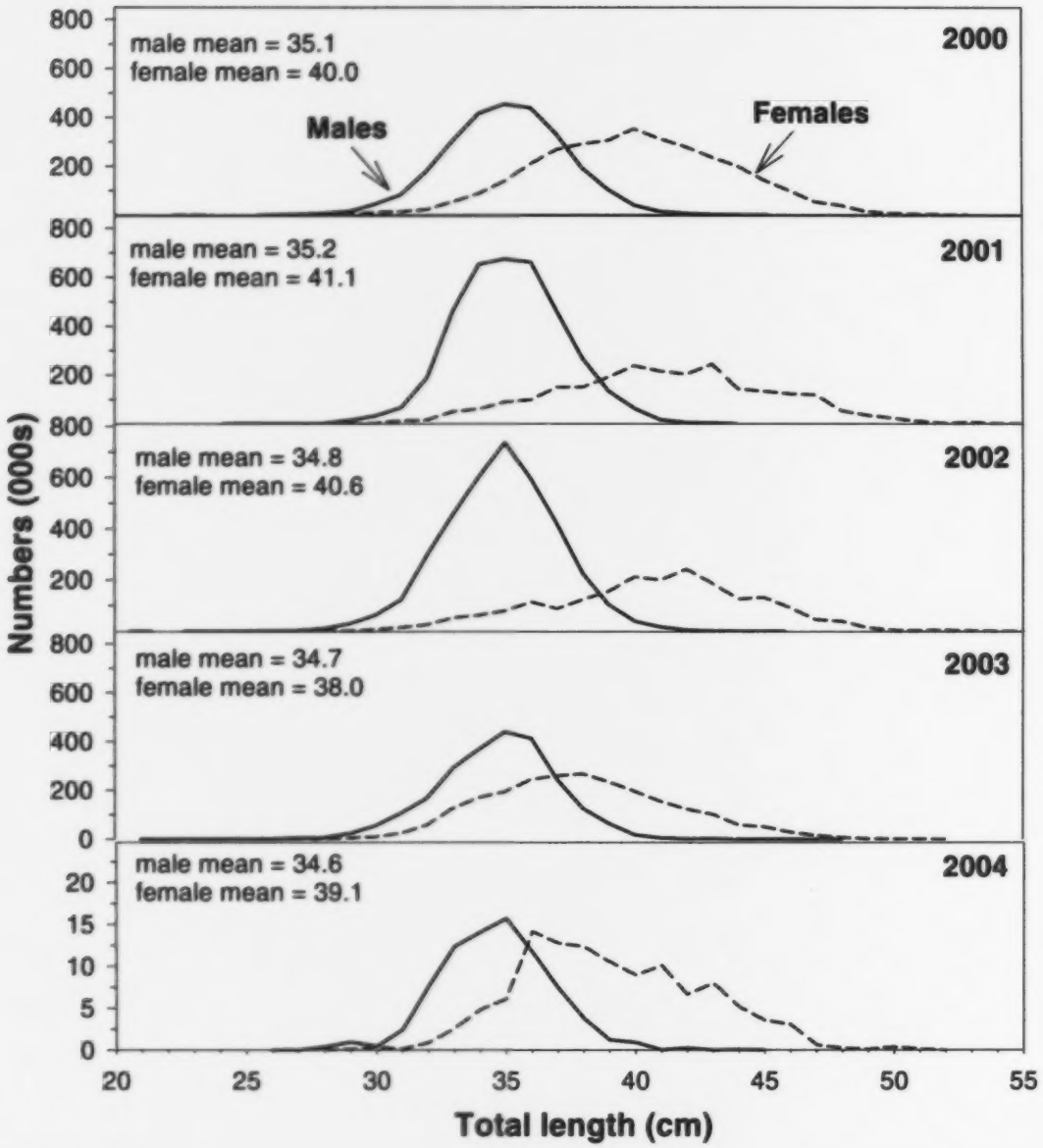

Fig. 7. Georges Bank yellowtail flounder length frequency composition by sex for the Canadian fishery, 2000-2004. (Note: scale is different for 2004).

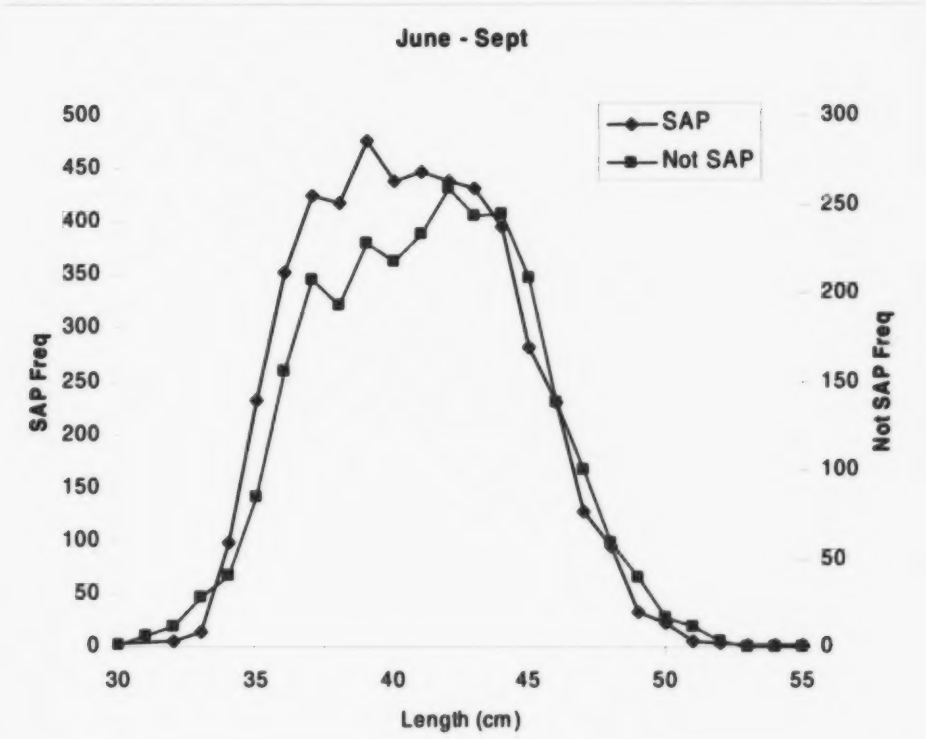

Fig. 8. Comparison of kept length frequencies from observer trips inside and outside Closed Area II during the Special Access Program (June to September).

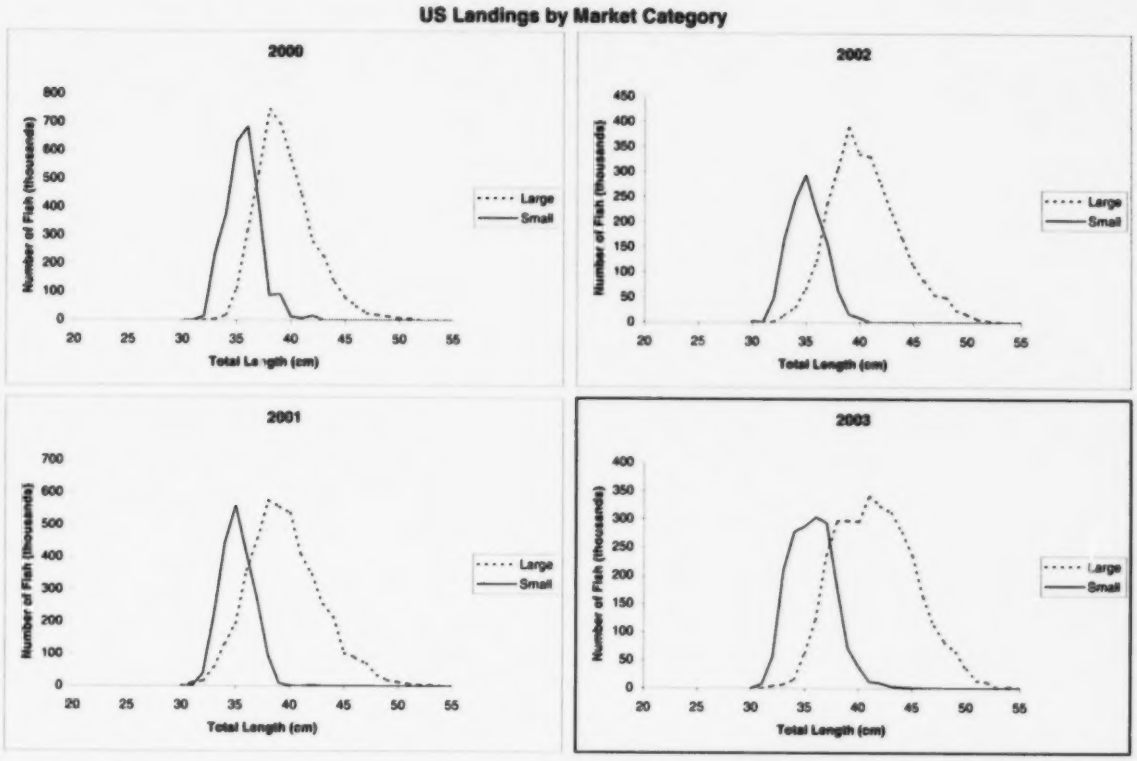

Fig 9. US landings of Georges Bank yellowtail by market category.

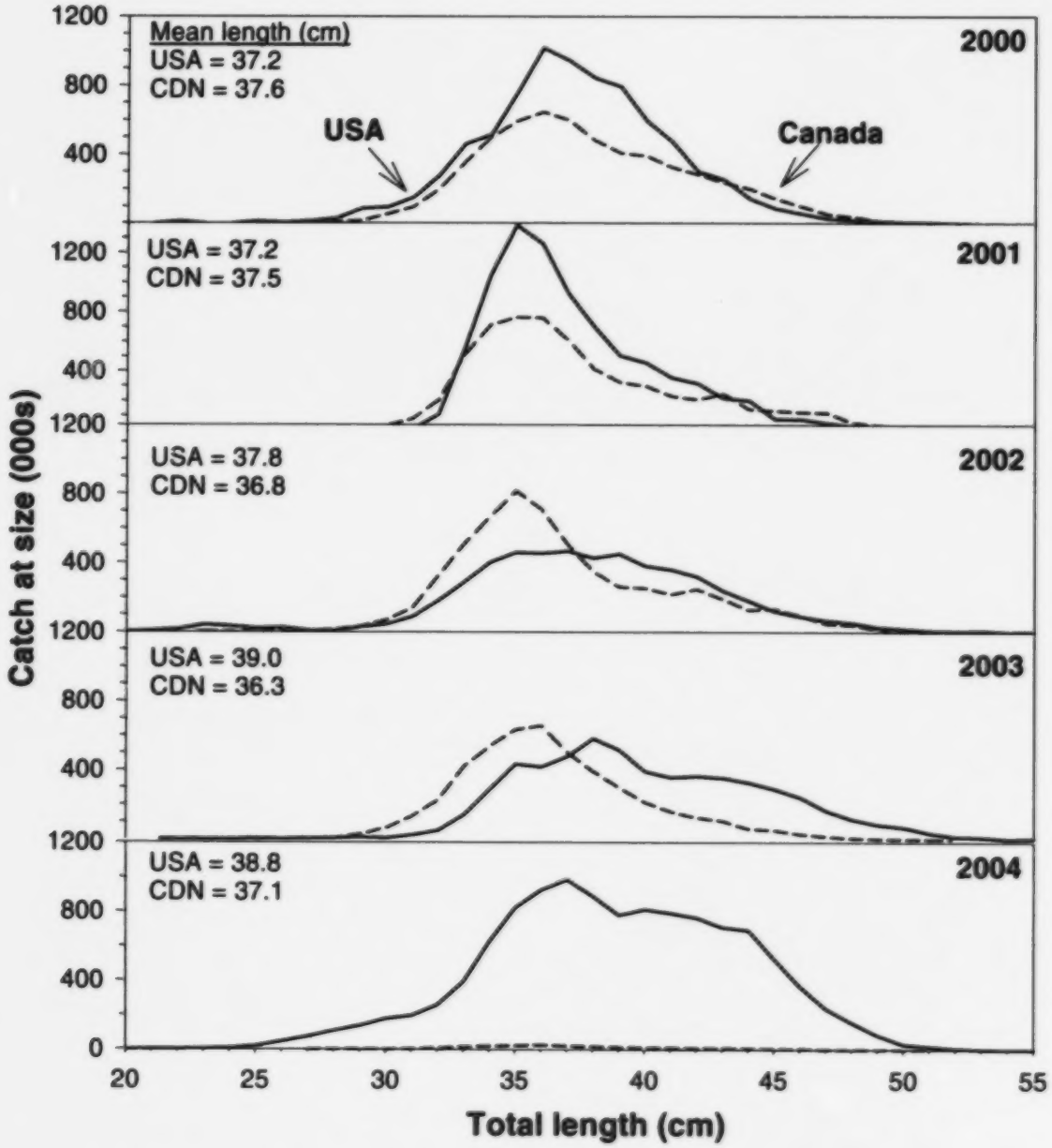

Fig.10. Comparison of Georges Bank yellowtail flounder catch at size from the Canadian and USA fisheries 2000-2004.

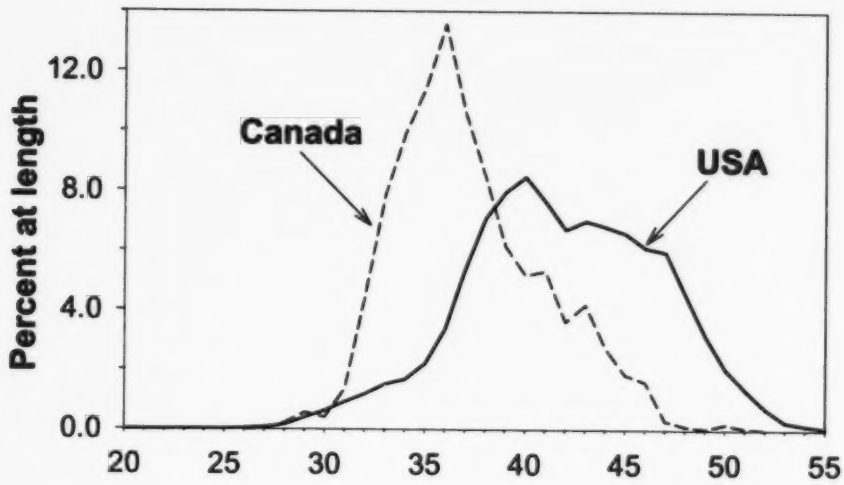

Fig. 11. Comparison of Georges Bank yellowtail flounder proportion at size from the Canadian and USA fisheries in 2004.

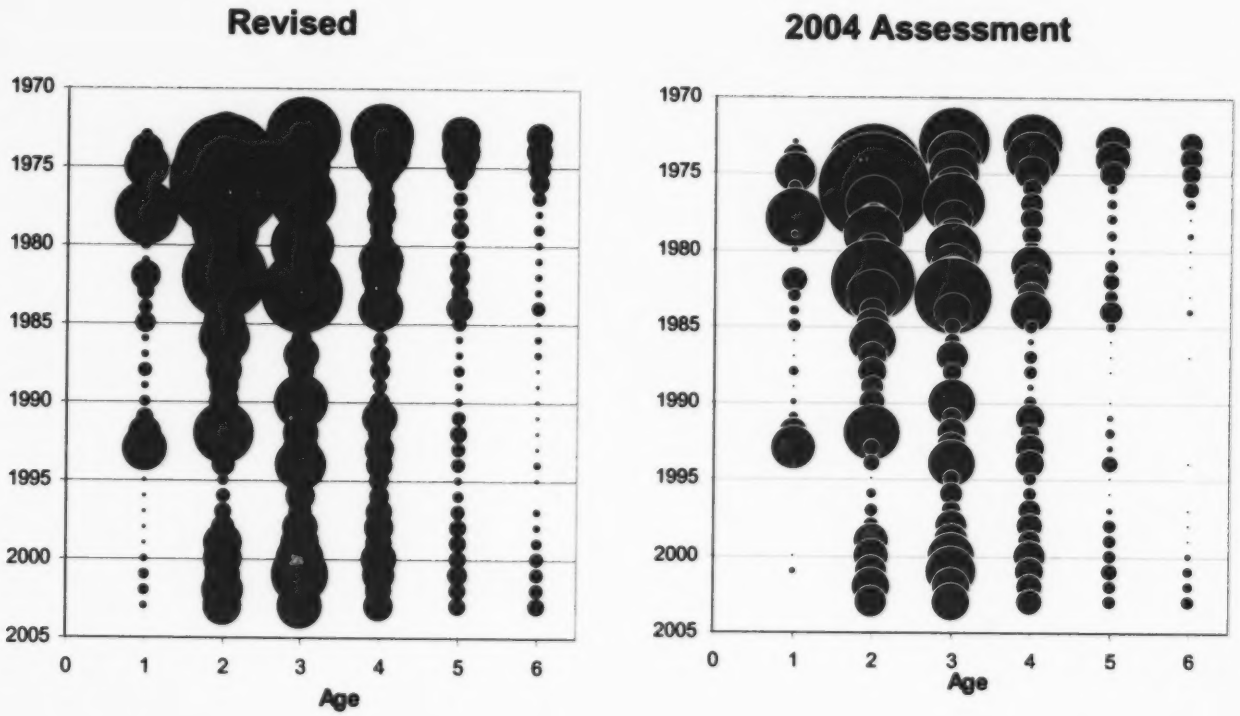

Fig. 12. Comparison of revised CAA from 2005 benchmark review and CAA from 2004 assessment for Georges Bank yellowtail flounder from the Canadian fishery, 1993-2003. (The area of the bubble is proportional to the magnitude of the catch).

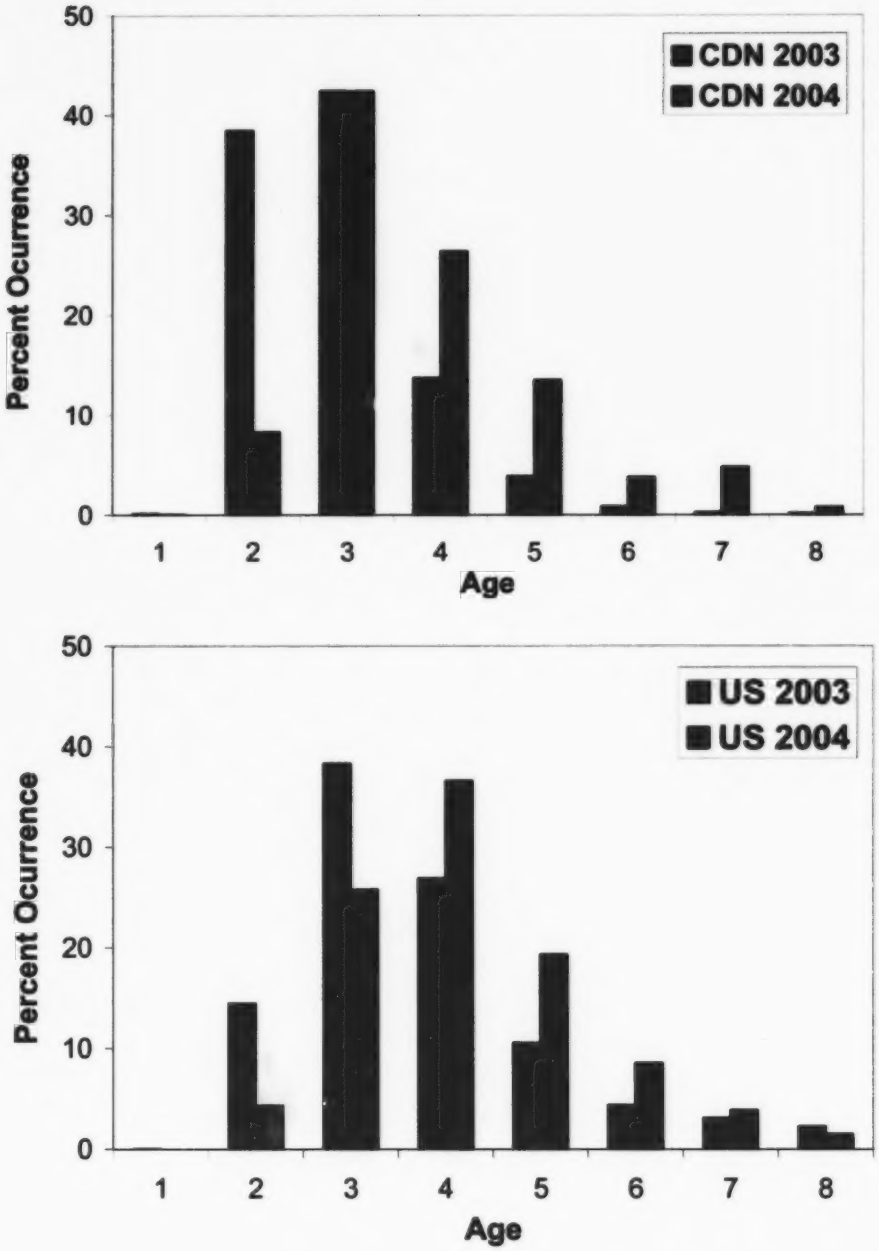

Fig. 13. Comparison of 2003 and 2004 Georges Bank yellowtail flounder landings at age for Canada (upper panel) and the USA (lower panel). (Note: discards for both nations are not included).

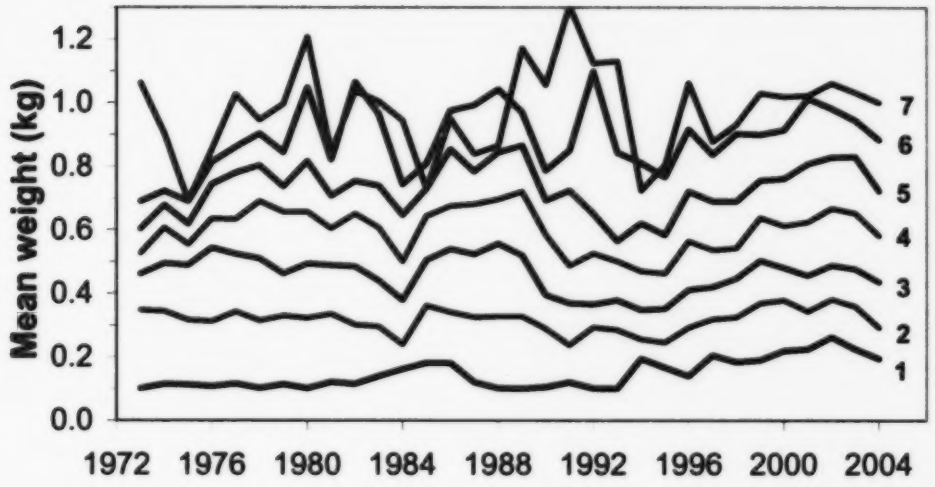

Fig. 14. Mean weight (kg) at age for yellowtail flounder from the Canadian commercial fishery, 1973-2004.

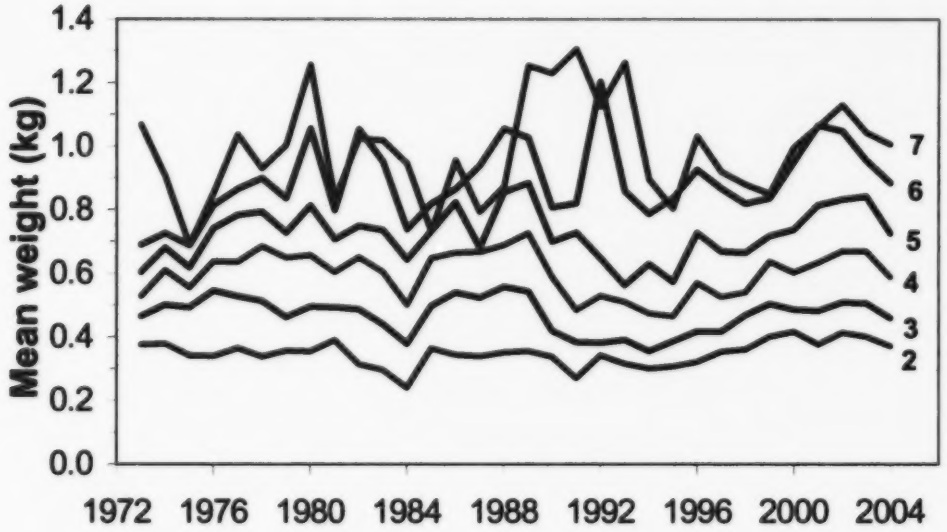

Fig. 15. Mean weight (kg) at age for yellowtail flounder from the US commercial fishery, 1973-2004.

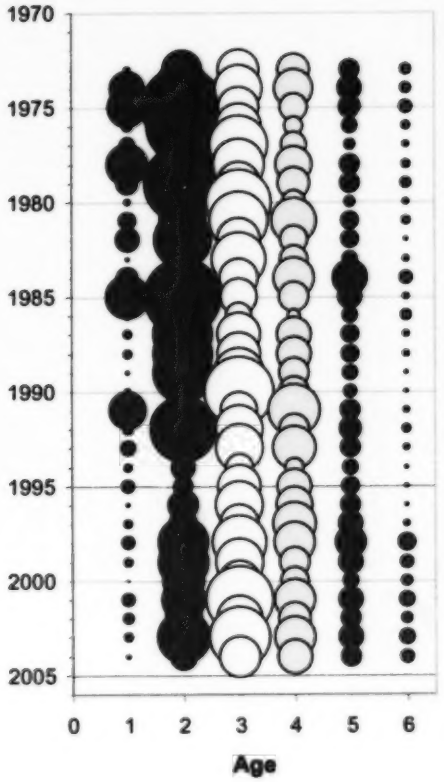

Fig. 16. Discards at age for yellowtail flounder from the Canadian scallop fishery on Georges Bank, 1973-2004. (The area of the bubble is proportional to the magnitude of the discarded catch).

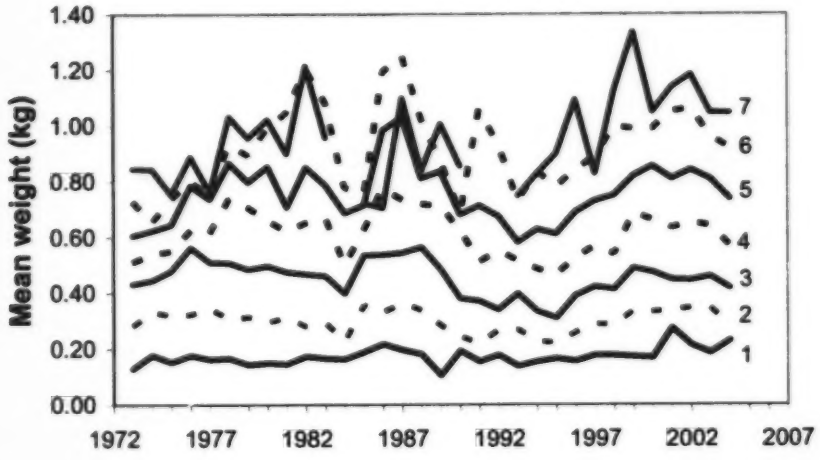

Fig. 17. Mean weight at age (kg) for yellowtail flounder from the Canadian scallop fishery on Georges Bank, 1973-2004.

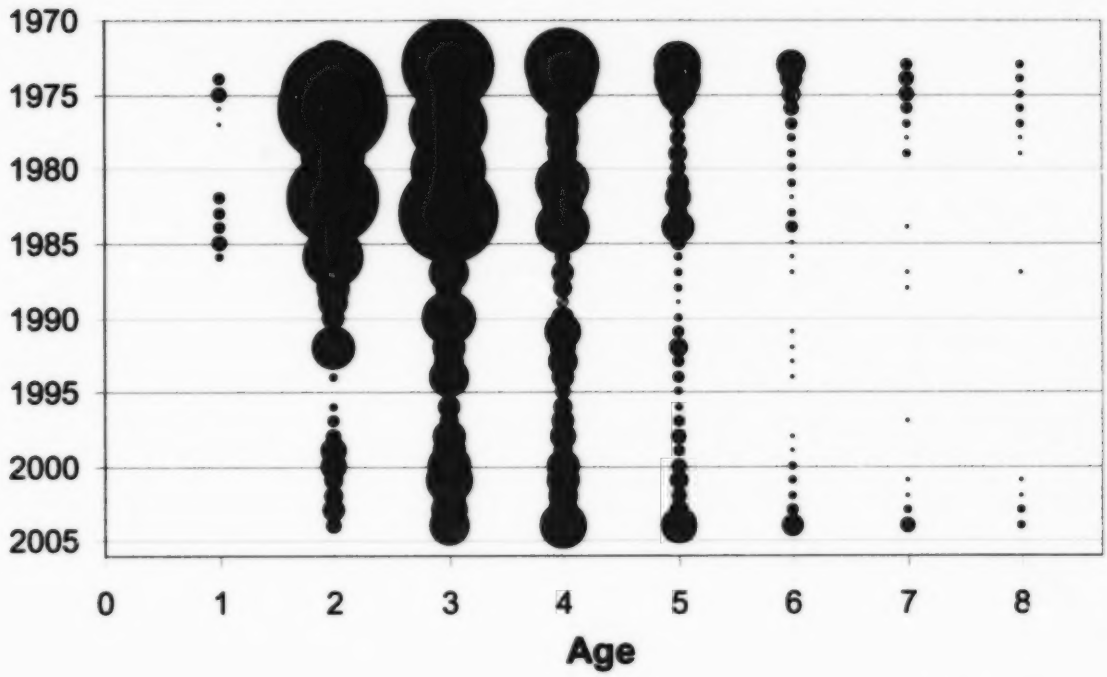

Fig. 18. Catch at age for Georges Bank yellowtail flounder, Canadian and USA fisheries combined, 1973-2004. (The area of the bubble is proportional to the magnitude of the catch).

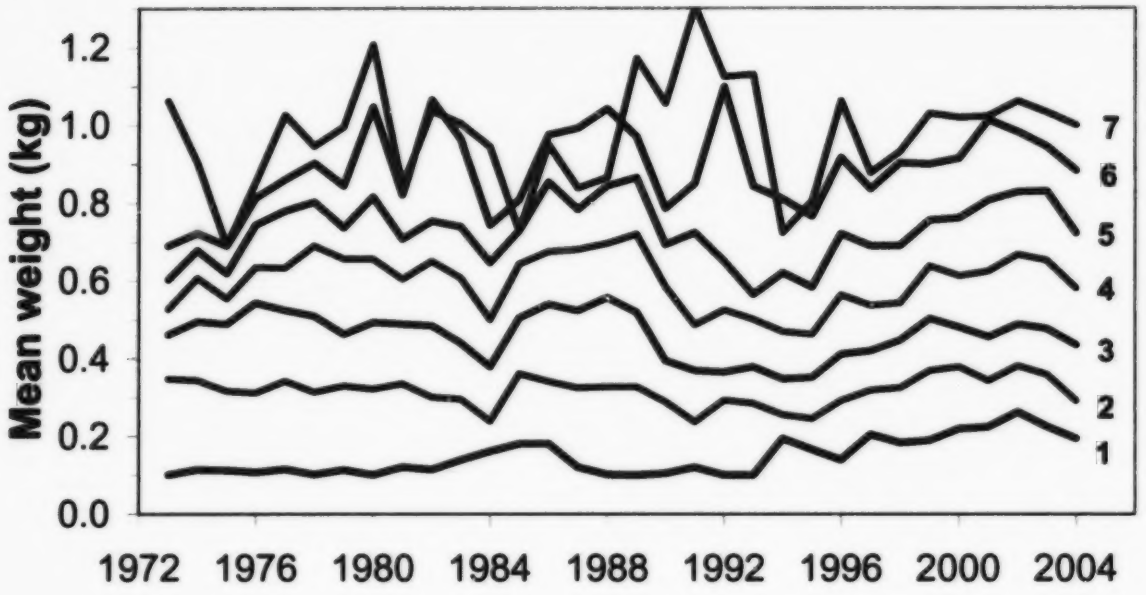

Fig. 19. Trends in mean weight at age from the 5Zjhmn yellowtail fishery, 1973 to 2003 (Canada and USA combined including discards).

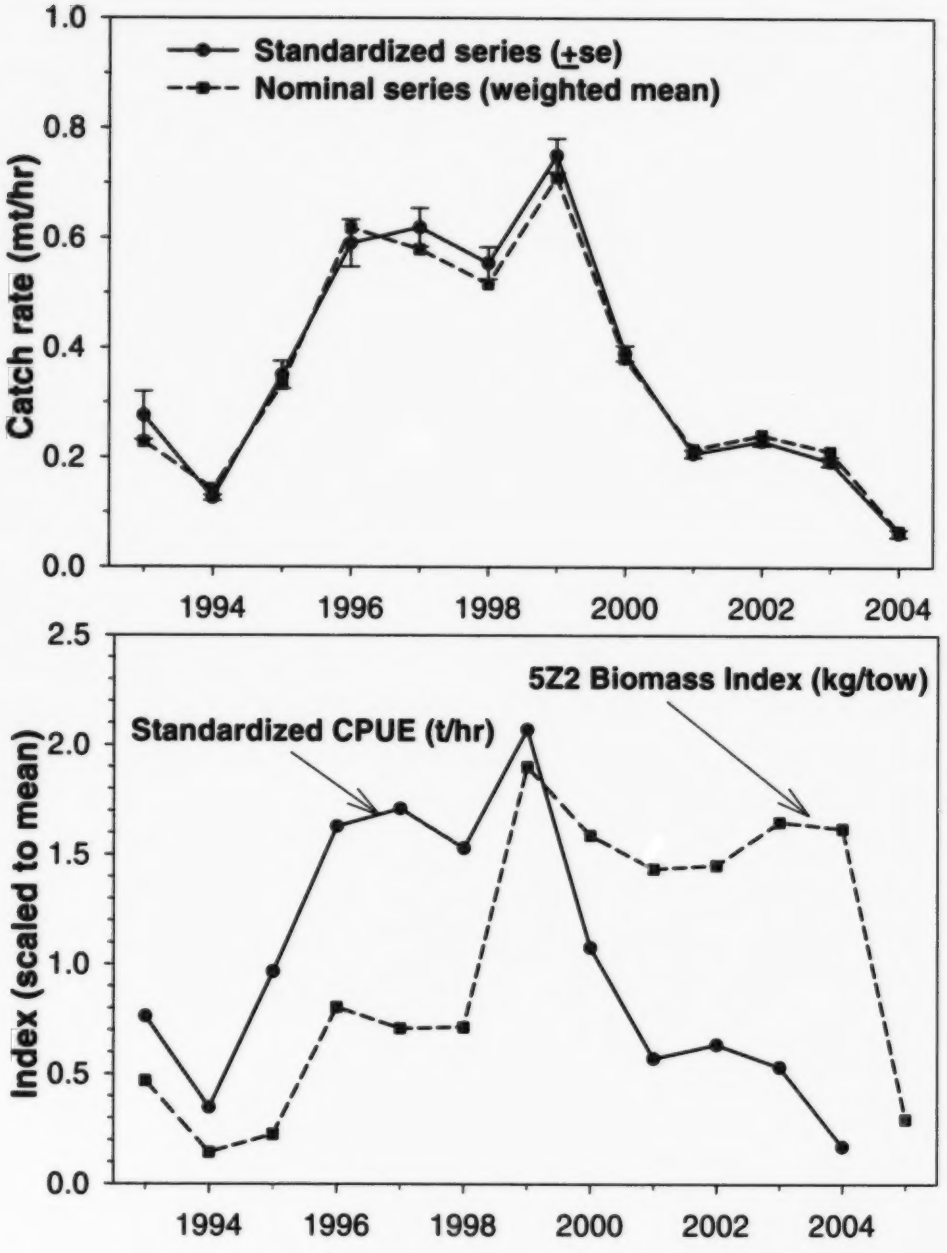

Fig. 20. Upper Panel: Nominal and standardized catch rates (tonnes/hour) for Canadian stern trawlers (TC 1-3) fishing for yellowtail flounder on Georges Bank based on directed trips in 5Zm with catches ≥ 2.0 t, 1993-2004. Lower Panel: Standardized CPUE for the Canadian fishery (1993-2004) and DFO spring survey biomass index for stratum 5Z2 (1993-2005).

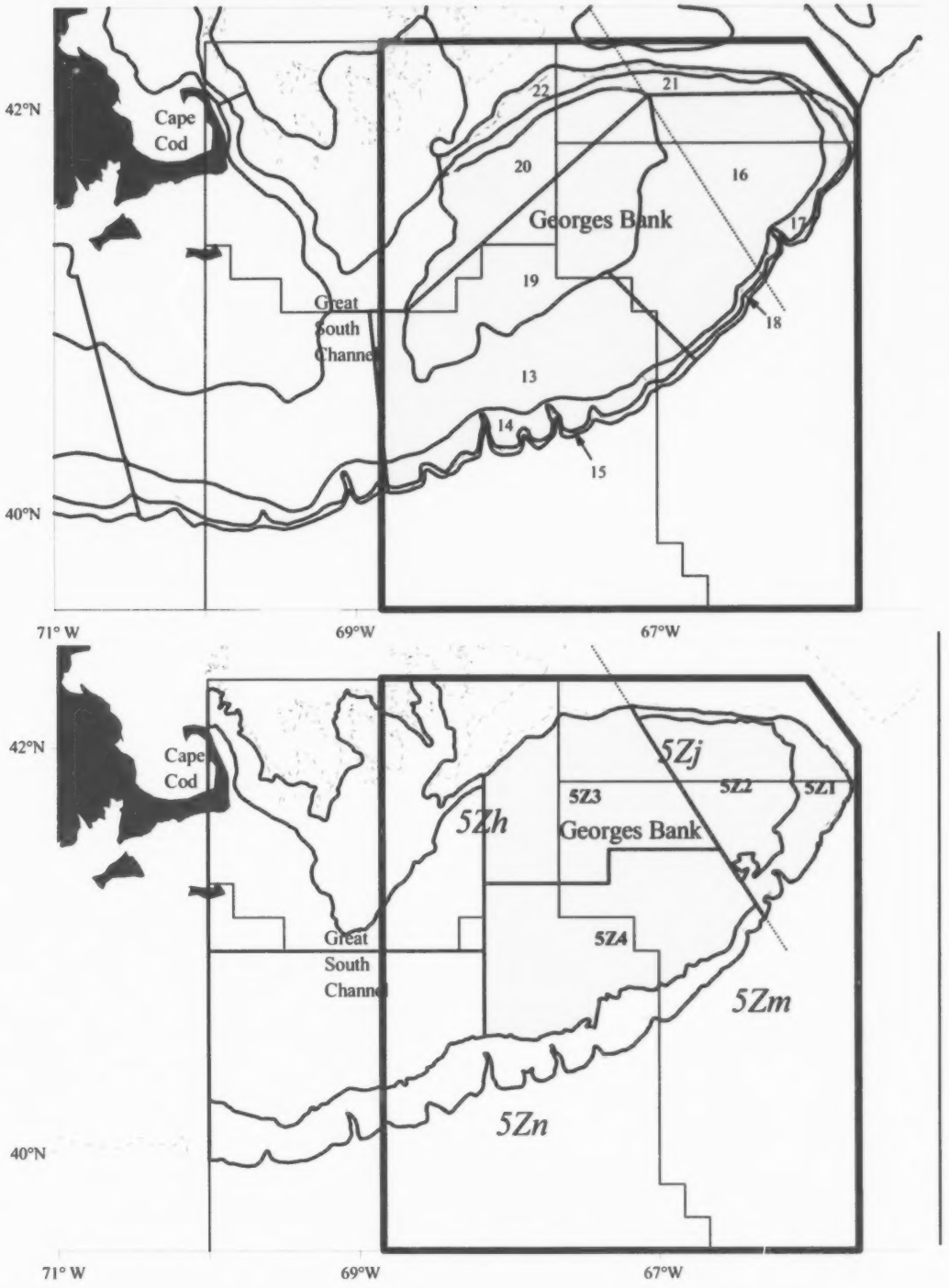

Fig. 21. NMFS (top) and DFO (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Note NMFS stratum 22 is not used in assessment.

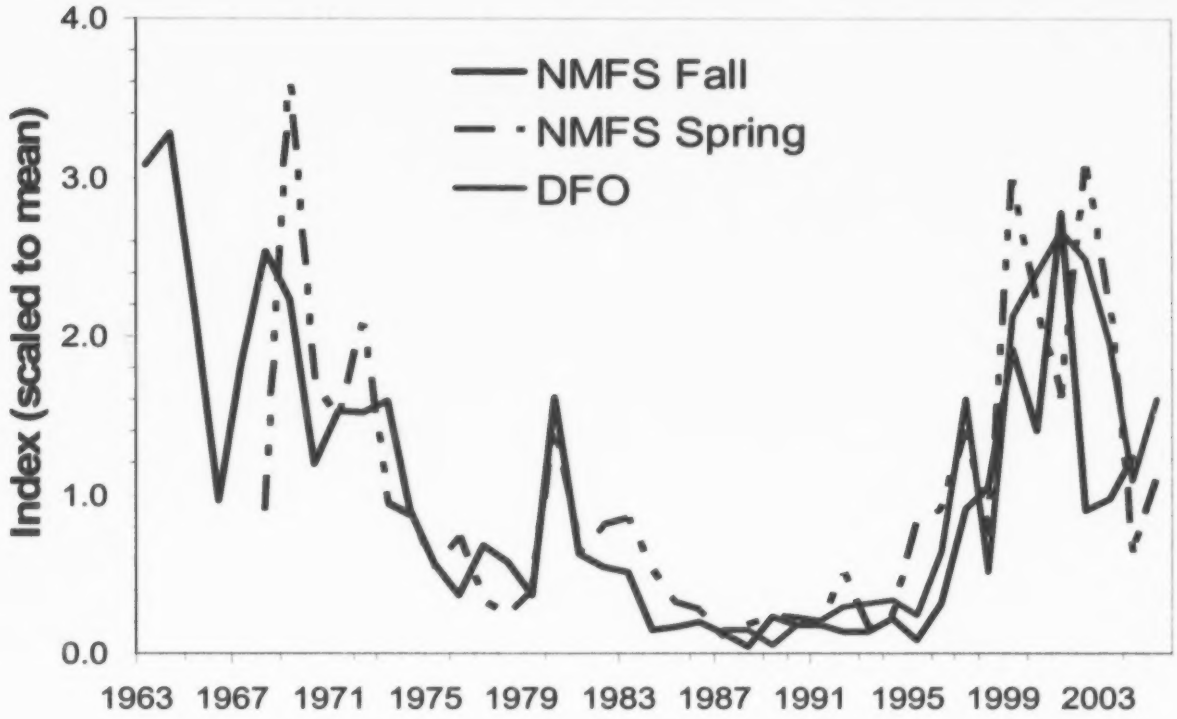

Fig. 22. NMFS and DFO spring and NMFS fall survey biomass indices for yellowtail flounder on Georges Bank.

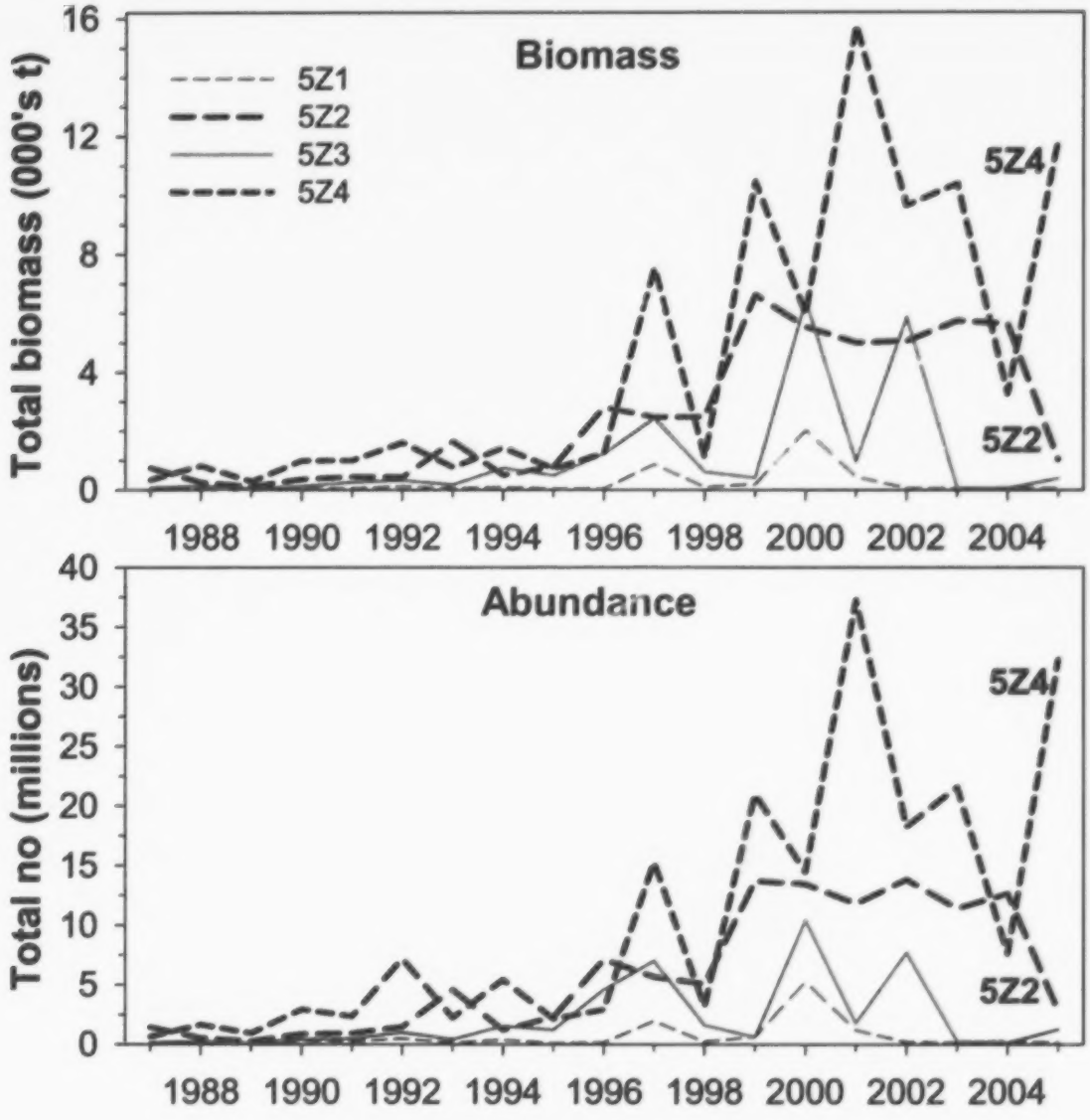

Fig. 23. DFO spring survey estimates of total biomass (top panel) and total number (bottom panel) by stratum area for yellowtail flounder on Georges Bank, 1987-2005.

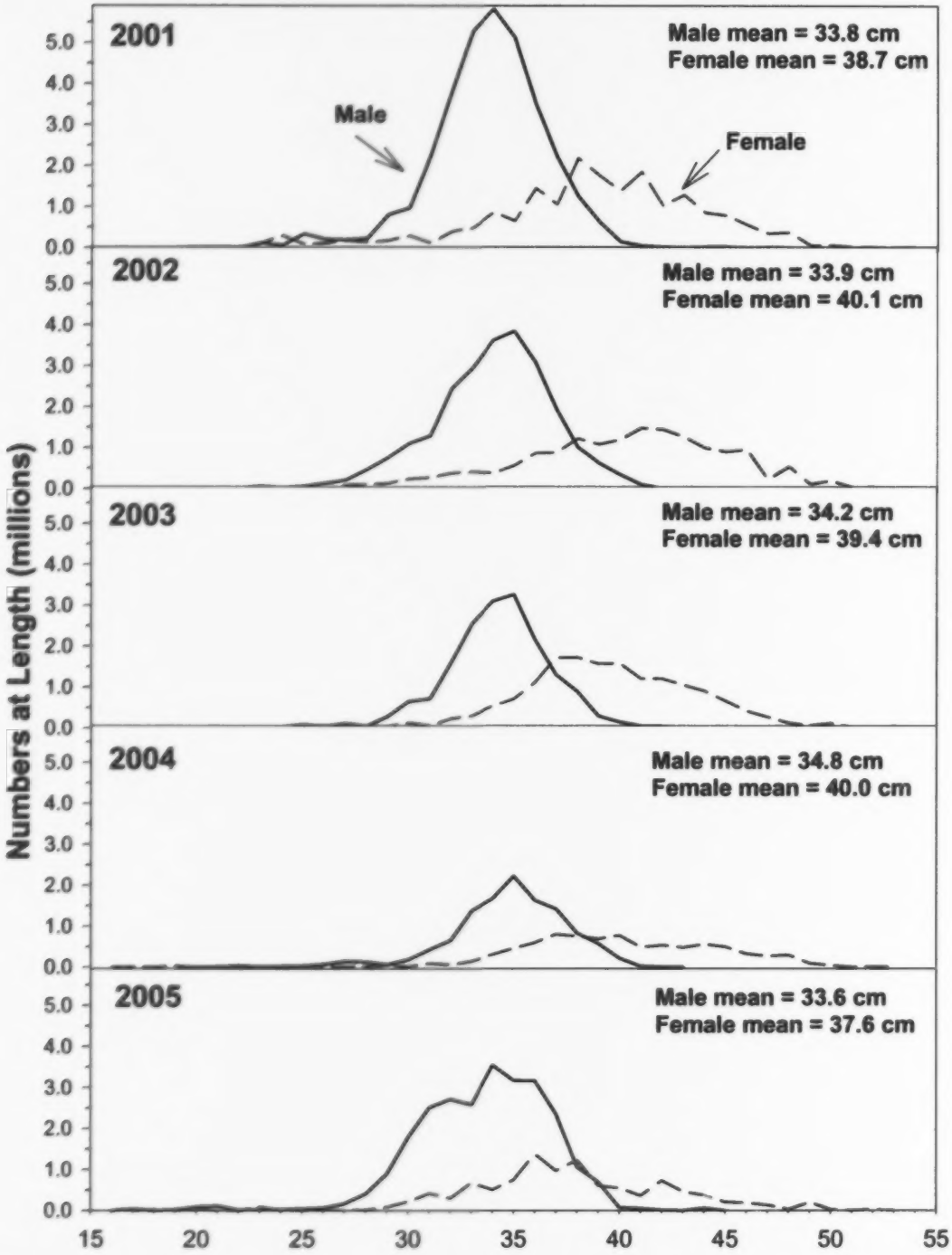

Fig. 24. Comparison of yellowtail flounder length composition in DFO spring surveys on Georges Bank, 2001-2005.

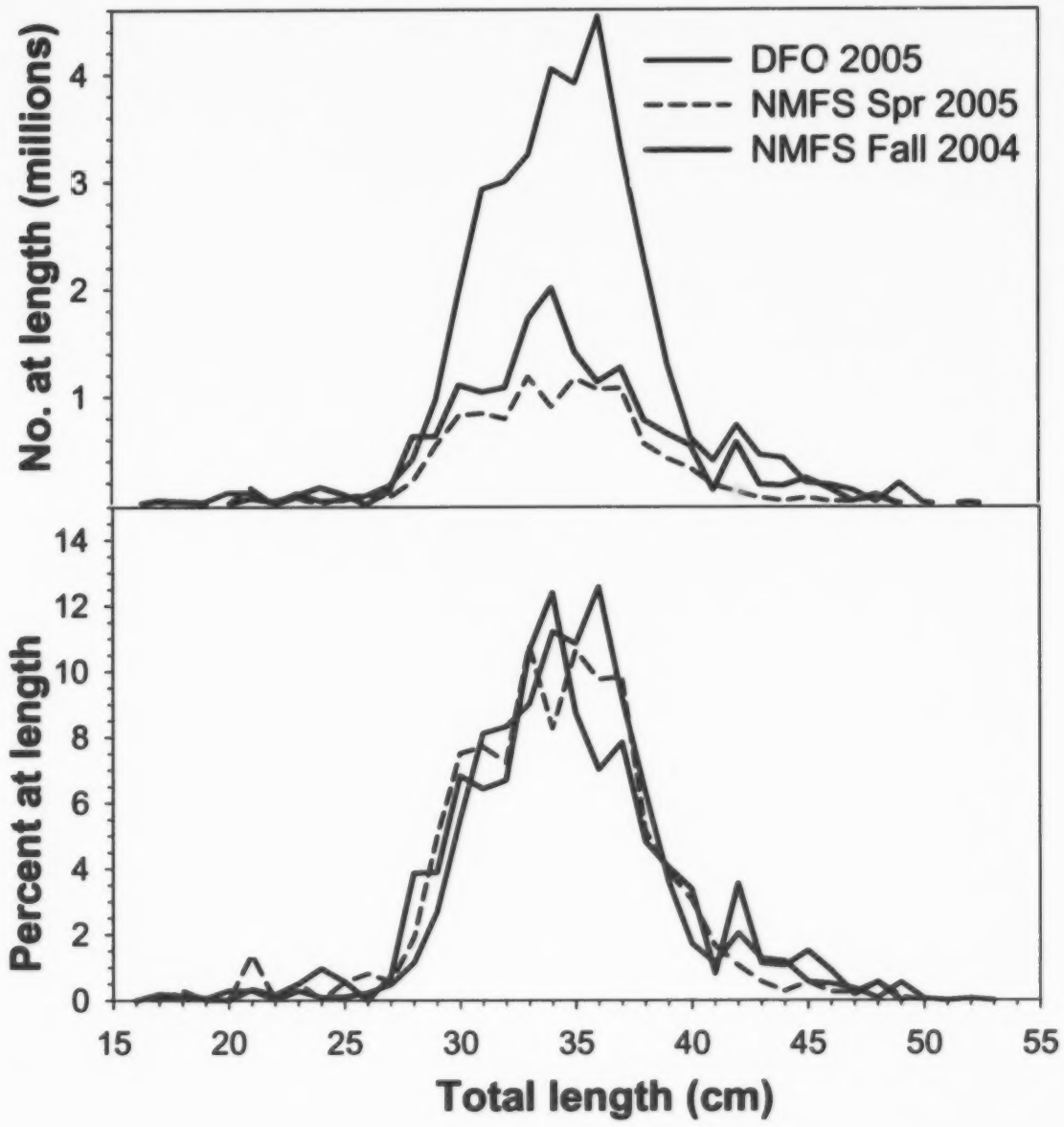

Fig. 25. Comparison of yellowtail flounder catch at length (upper panel) and proportion at length (lower panel) from the 2005 DFO, 2005 NMFS spring and 2004 NMFS fall surveys.

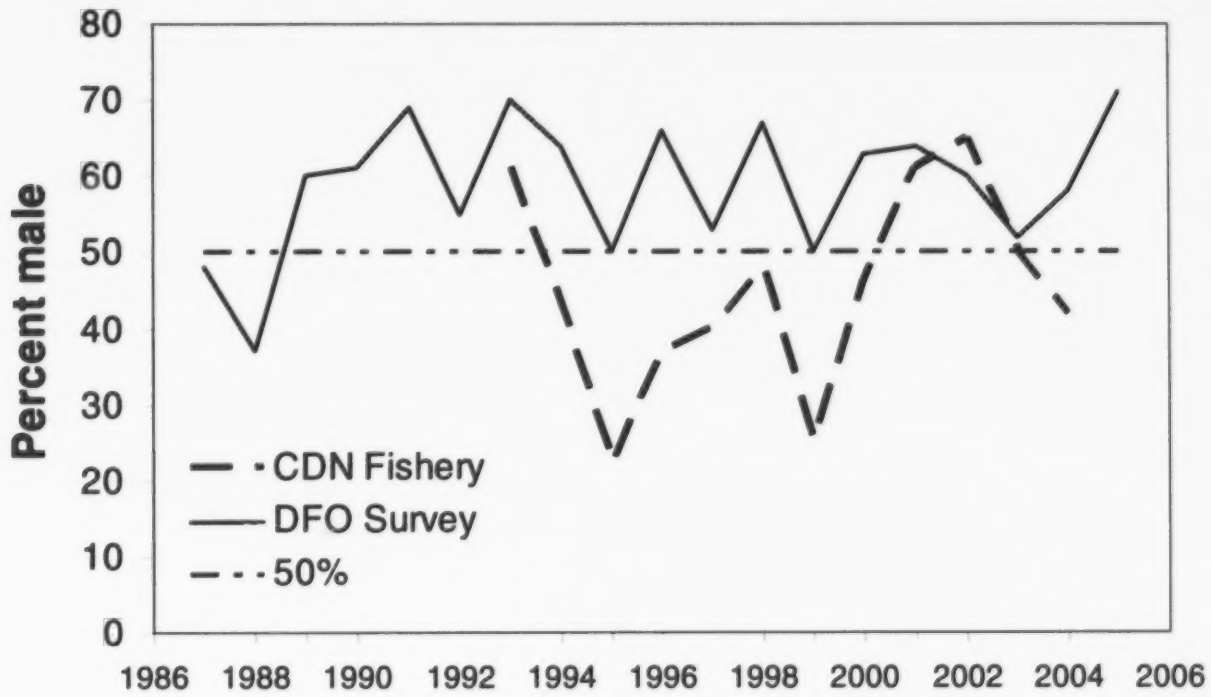

Fig 26. Percentage of male yellowtail flounder in the Canadian fishery (1993-2004) and DFO surveys (1987-2005).

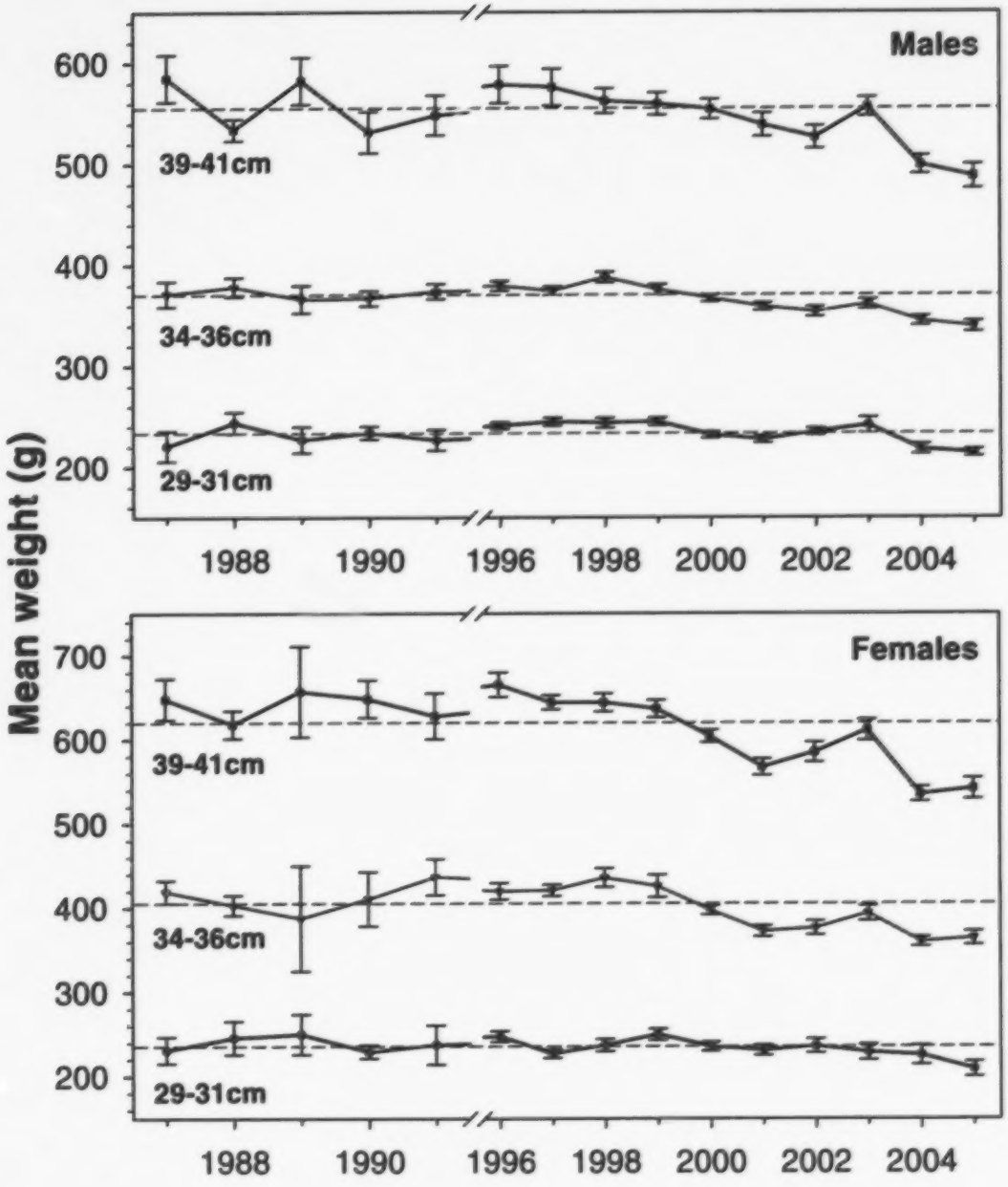

Fig 27. Trends in mean weight at 29-31cm, 34-36cm and 39-41cm cm TL for male and female yellowtail flounder sampled during February bottom trawl surveys conducted by DFO during 1987-1991 and 1996-2005. The dashed line is the long term mean for each series. Vertical bars represent ± 1SE.

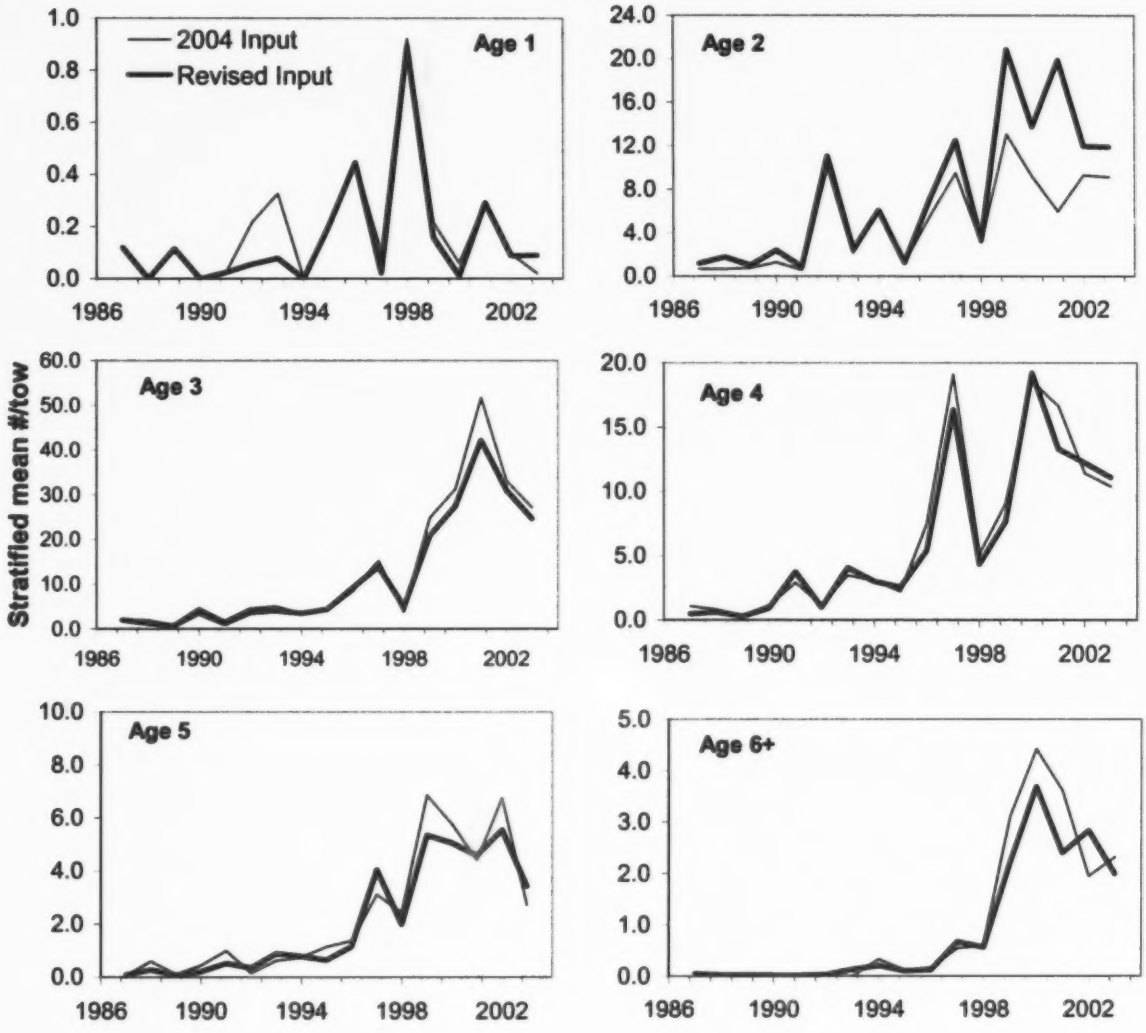

Fig. 28. Comparison of 1987-2003 DFO survey age-specific indices of abundance generated using borrowed age length keys from NMFS spring surveys only (2004 Assessment Input) and enhanced age length keys with additional ages from half 1 US port and observer samples (Revised Input).

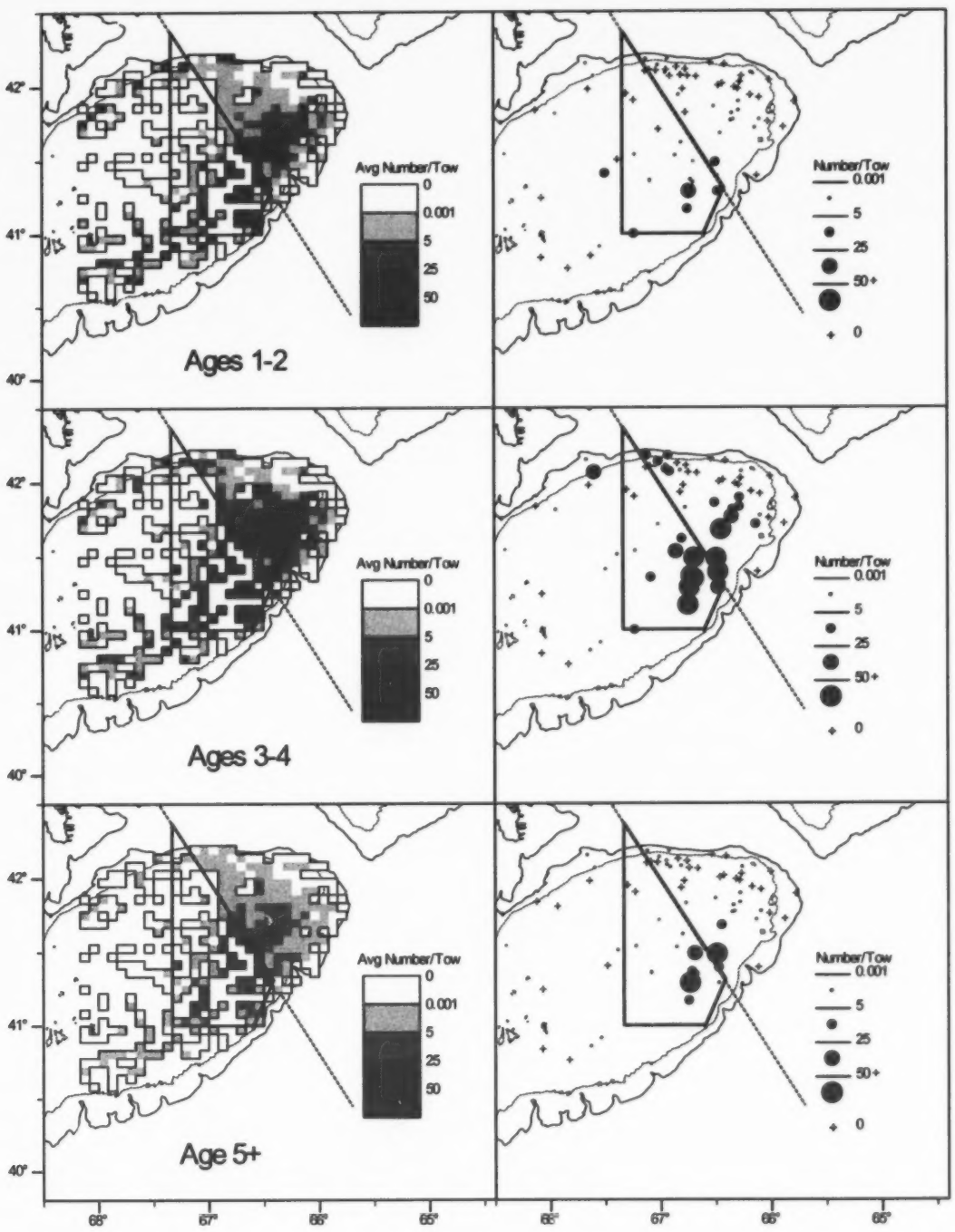

Fig. 29. The distribution of catches (#/tow) of yellowtail flounder (solid circles) in the 2005 DFO survey, compared with the average distribution for 1995-2004 (3x5 minute shaded rectangles) for ages 1-2, 3-4 and 5+. The boundary of Closed Area II is shown in red (left side) and black (right side).

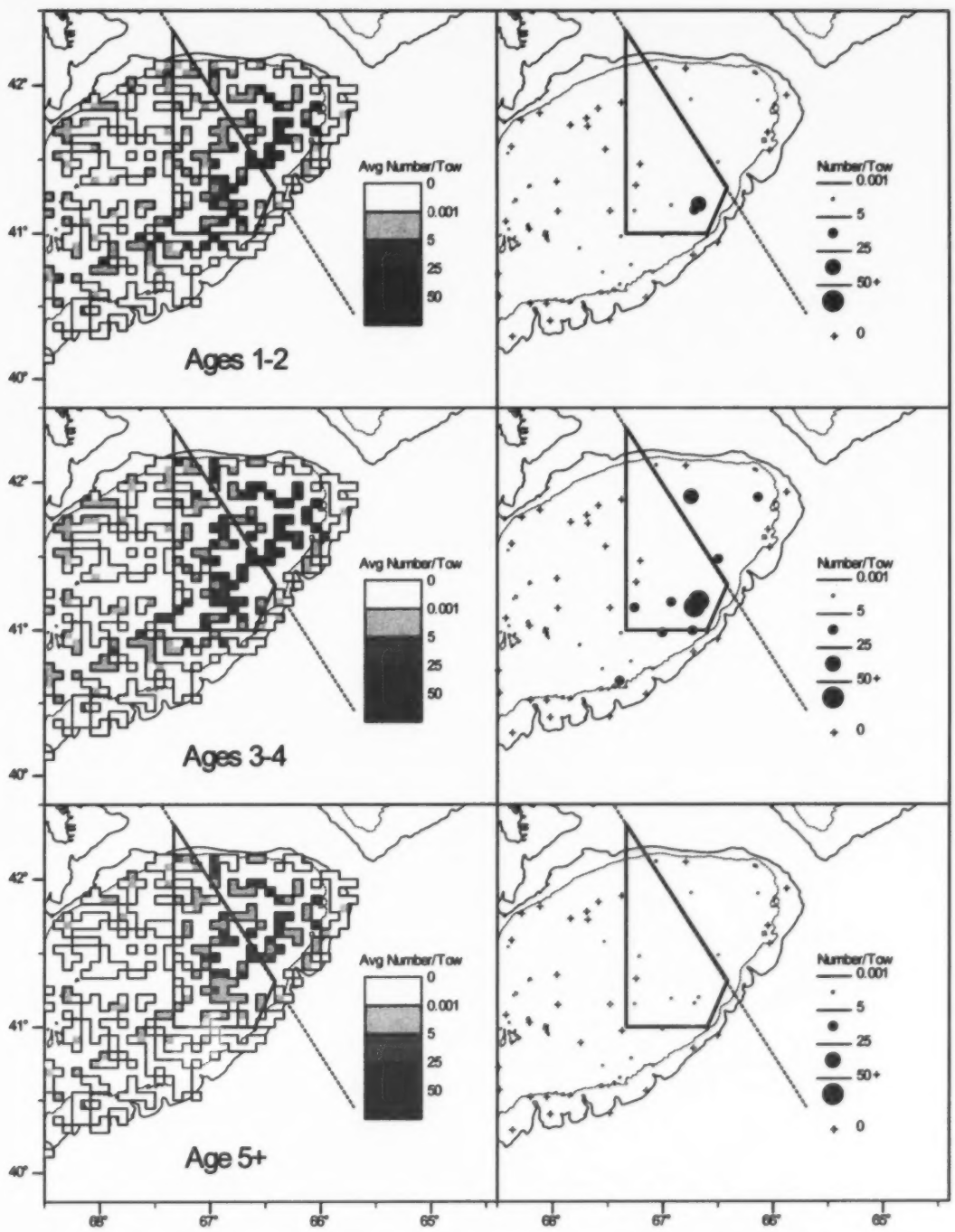

Fig. 30. The distribution of catches (#/tow) of yellowtail flounder (solid circles) in the 2005 NMFS spring survey, compared with the average distribution for 1995-2004 (3x5 minute shaded rectangles) for ages 1-2, 3-4 and 5+. The boundary of Closed Area II is shown in red (left side) and black (right side).

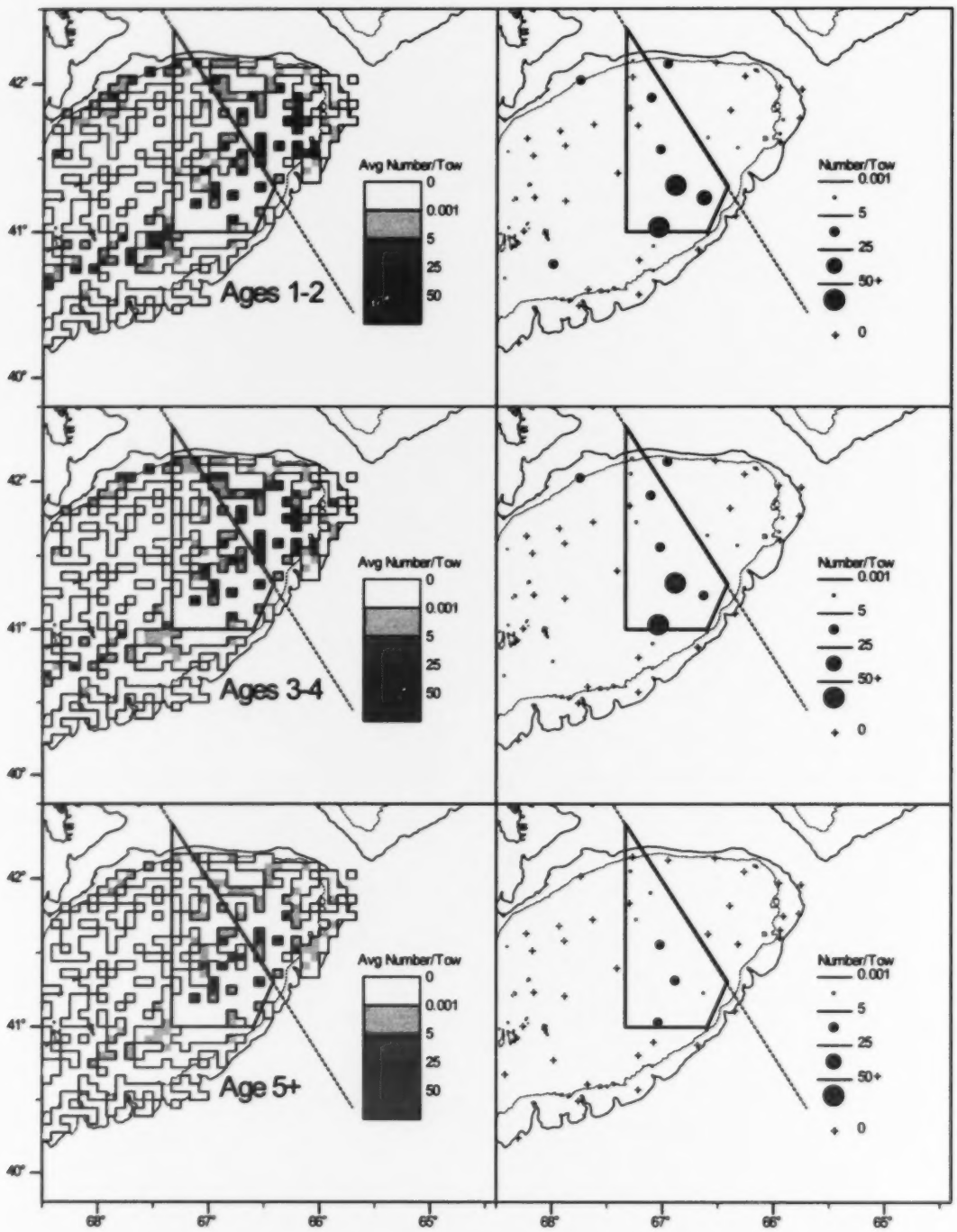

Fig. 31. The distribution of catches (#/tow) of yellowtail flounder (solid circles) in the 2005 NMFS fall survey, compared with the average distribution for 1995-2004 (3x5 minute shaded rectangles) for ages 1-2, 3-4 and 5+. The boundary of Closed Area II is shown in red (left side) and black (right side).

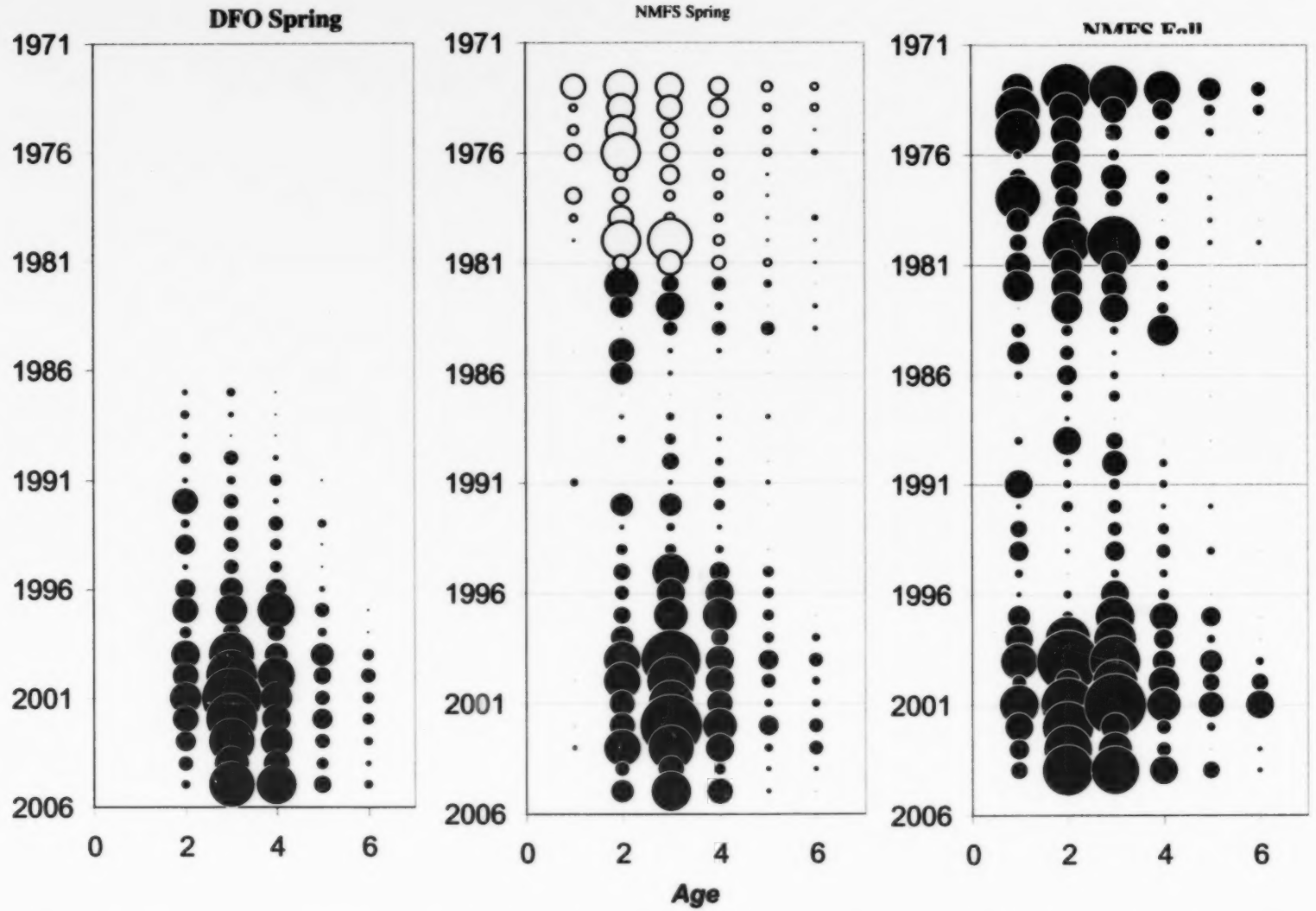

Fig. 32. Age specific indices of abundance for the DFO spring (1987-2005), NMFS spring (1968-2005), and NMFS fall (1963-2004) surveys (bubble is proportional to the magnitude) The yellow symbols in the NMFS spring series denote the period when the Yankee 41 net was used. Refer to Tables 8, 9 and 10 for the absolute value of the indices.

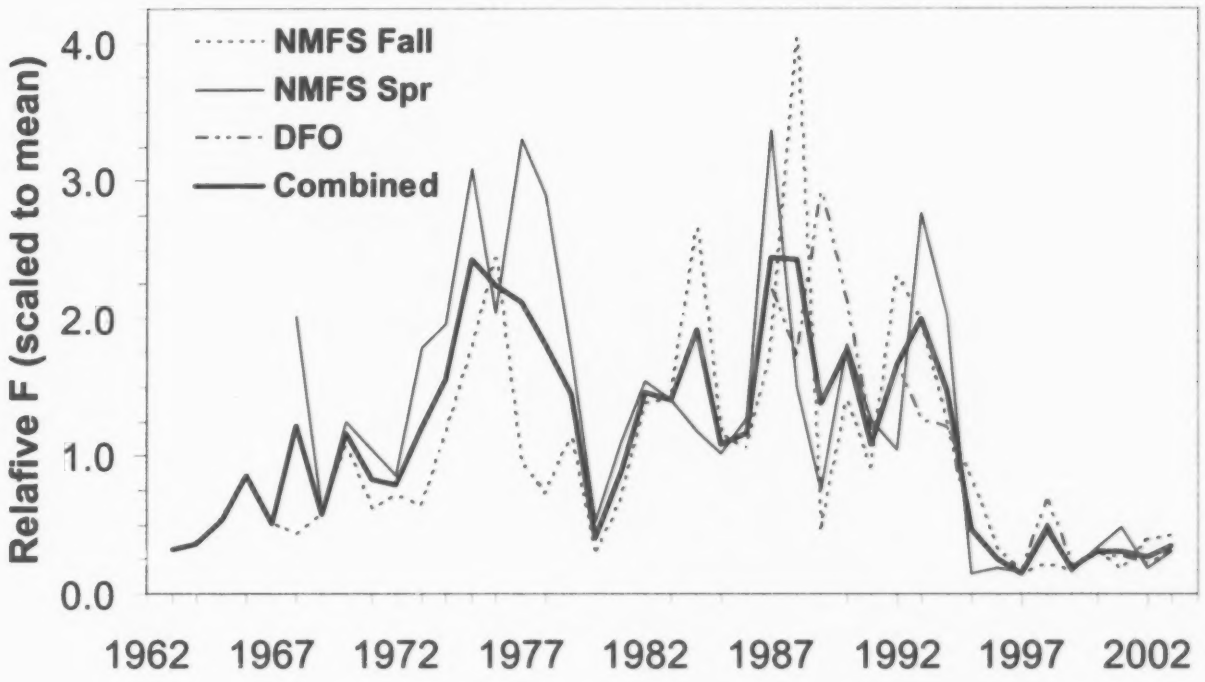

Fig. 33. Trends in relative fishing mortality (catch biomass/survey biomass), standardized to the mean for 1987-2004.

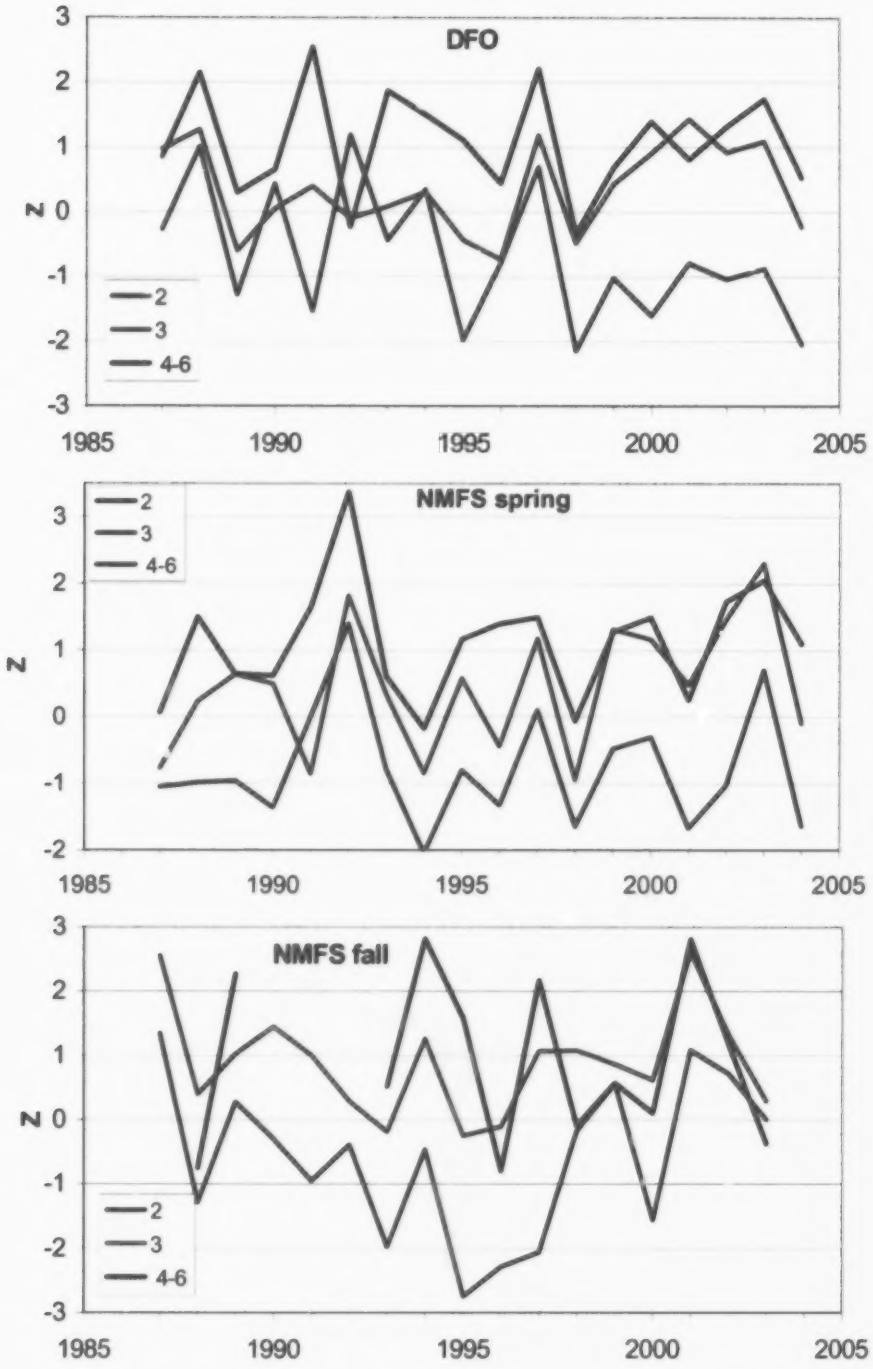

Fig. 34. Trends in total mortality (Z) for ages 2, 3, and 4-6 from DFO, NMFS Spring and NMFS Fall bottom trawl surveys, 1987-2003/2004.

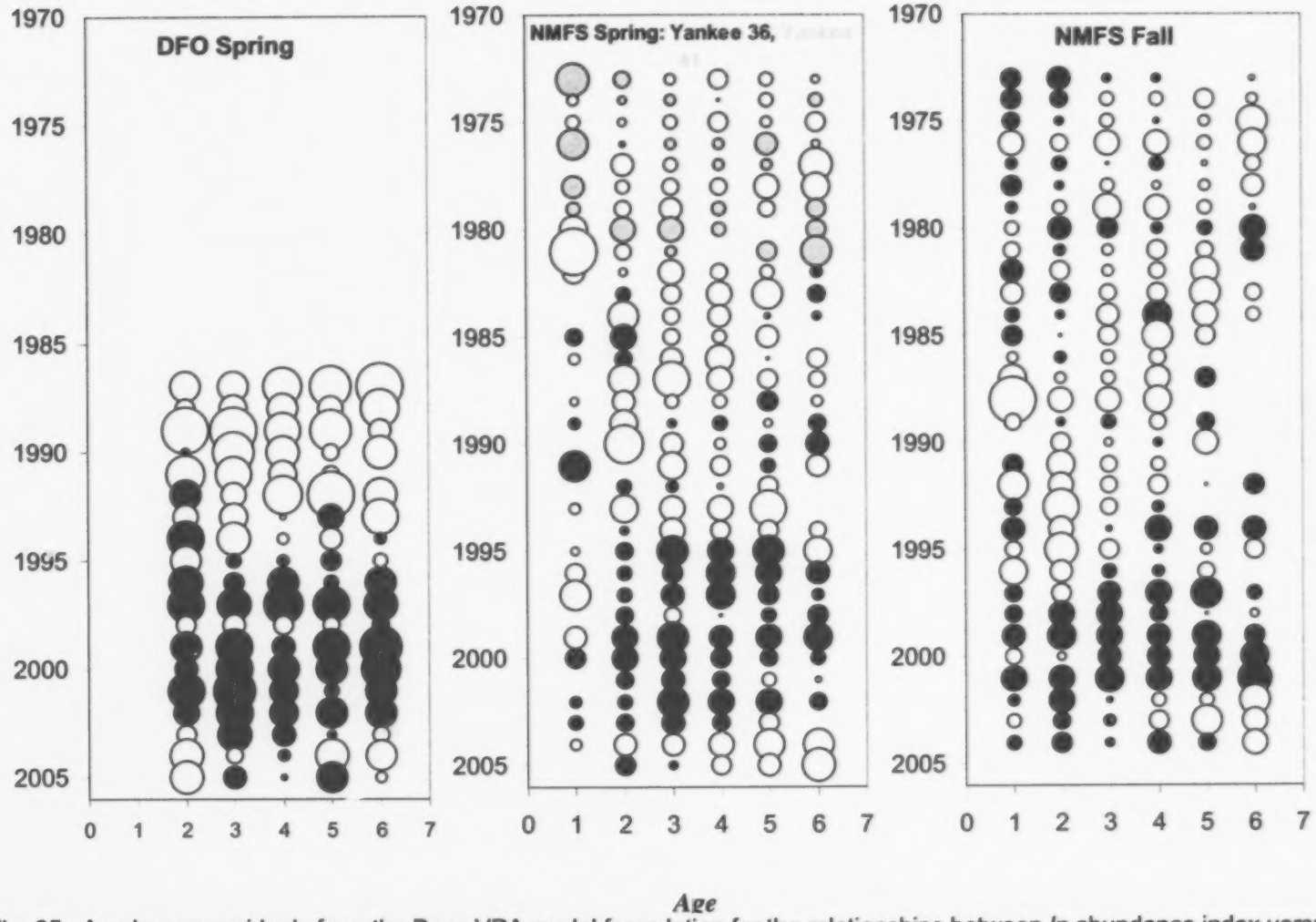

Fig. 35. Age by age residuals from the Base VPA model formulation for the relationships between *ln* abundance index versus *ln* population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The grey shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. The open symbols denote negative residuals, and closed symbols denote positive residuals.

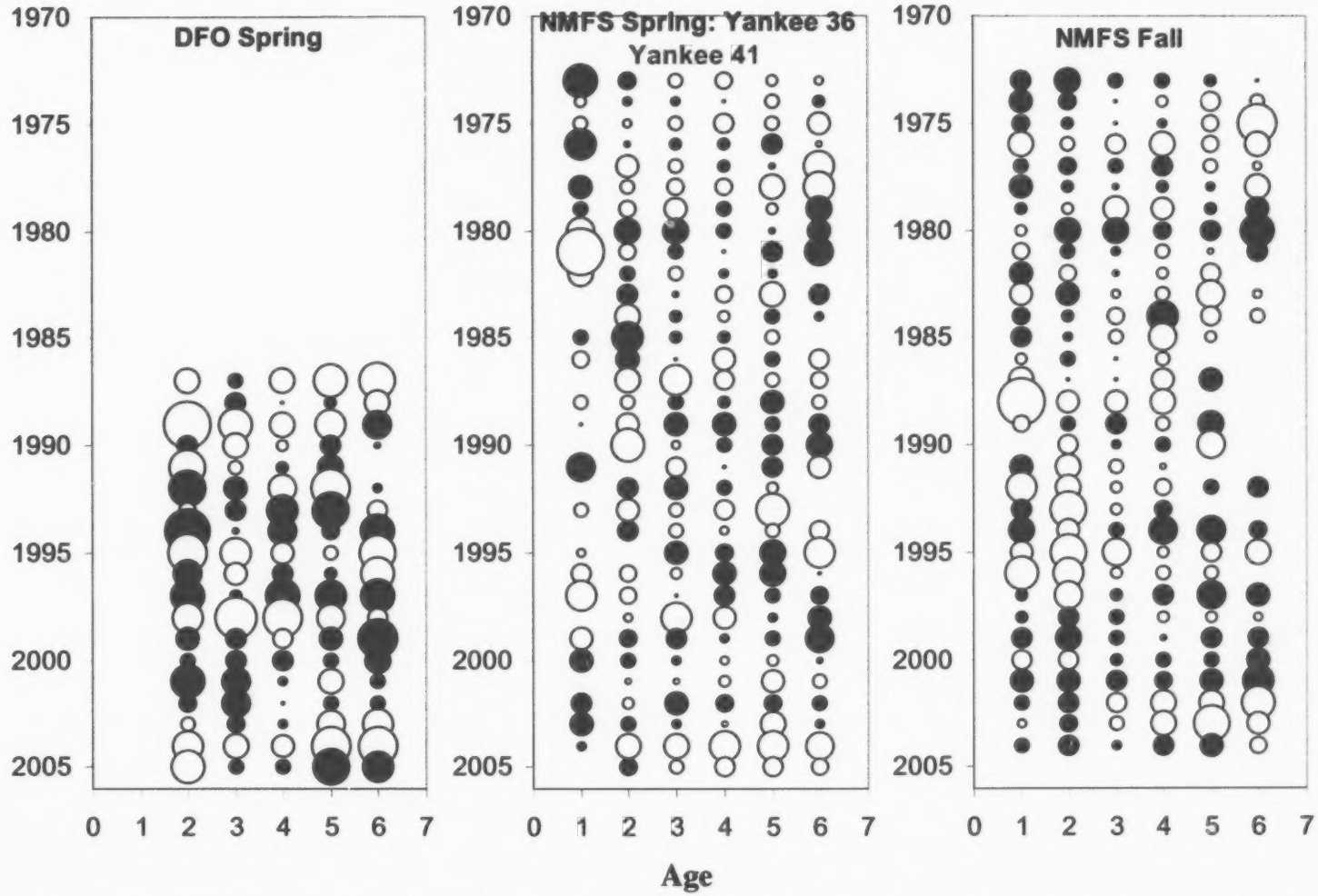

Fig. 36. Age by age residuals from the major change VPA formulation for the relationships between *ln* abundance index versus *ln* population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude). The red shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. The open symbols denote negative residuals, and closed symbols denote positive residuals.

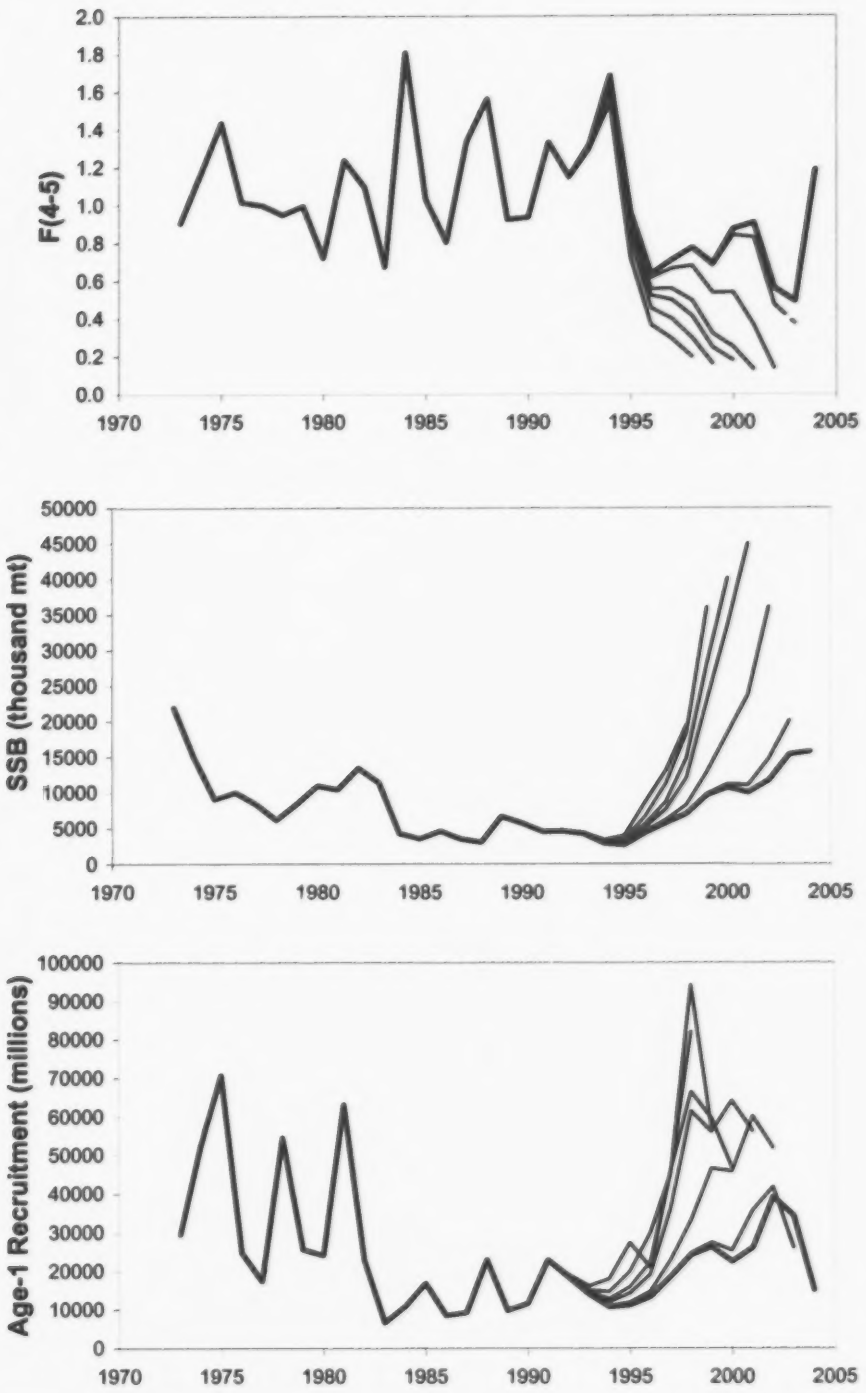

Fig. 37. Retrospective analysis of Georges Bank yellowtail flounder from the BaseVPA for age 4-5 fishing mortality (top panel), age 3+ biomass (middle panel) and age 1 recruits (lower panel) based on US NFT ADAPT software results.

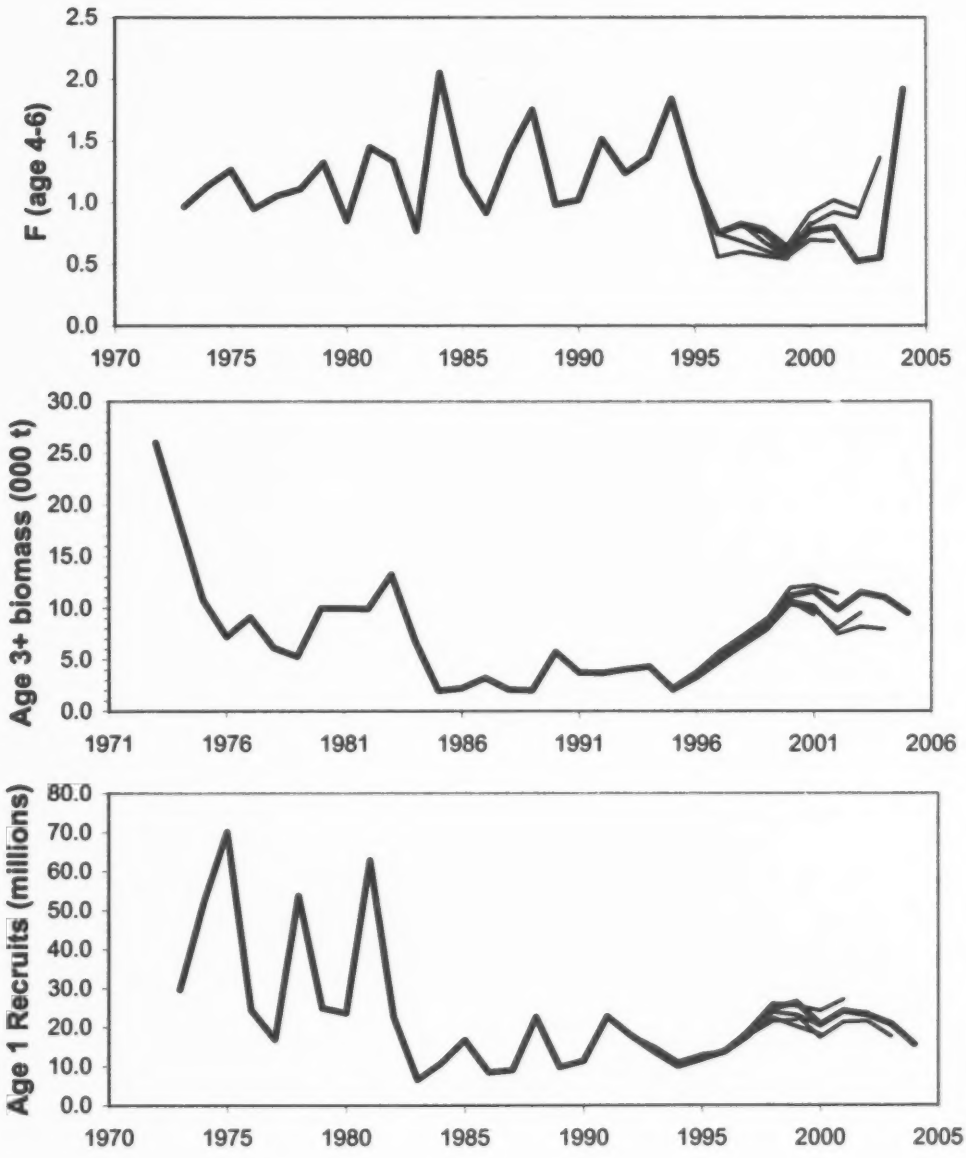

Fig. 38. Retrospective analysis of Georges Bank yellowtail flounder from the Major Change VPA for age 4-6 fishing mortality (top panel), age 3+ biomass (middle panel) and age 1 recruits (lower panel) based on Canadian ADAPT software results.

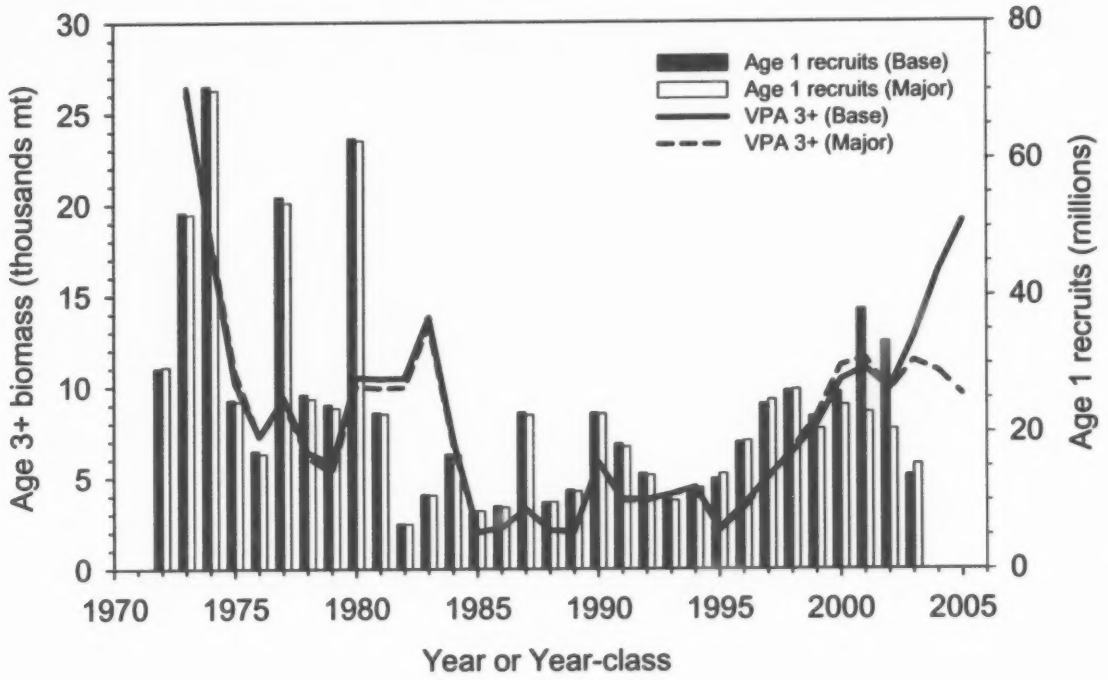

Fig. 39. Trends in and adult (age 3+) beginning of year biomass (000s) and age 1 recruits for Georges Bank yellowtail flounder as indicated from the Canadian ADAPT Base and Major Change VPA model formulations.

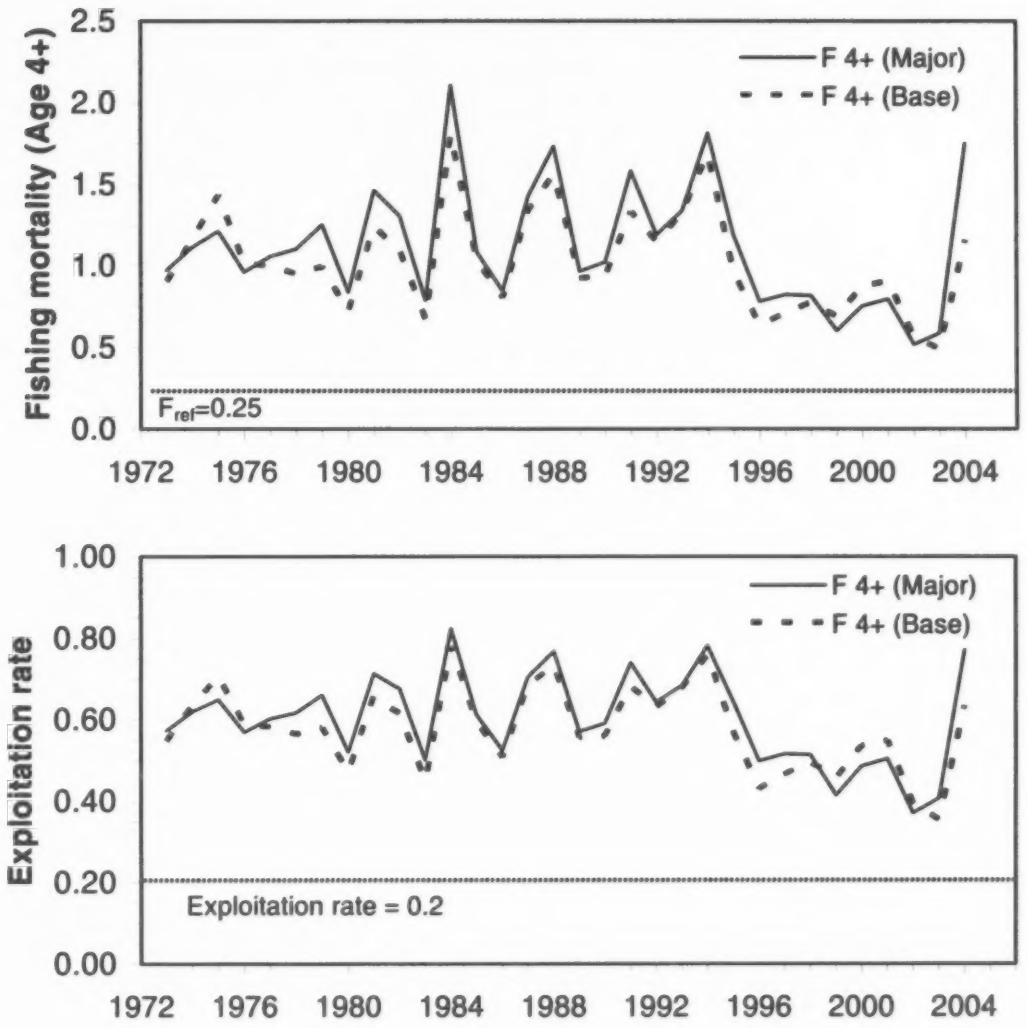

Fig. 40. Trends in fully recruited (age 4+) fishing mortality (upper panel) and exploitation rate (lower panel) for Georges Bank yellowtail flounder as indicated from the Canadian ADAPT Base and Major Change VPA model formulations.

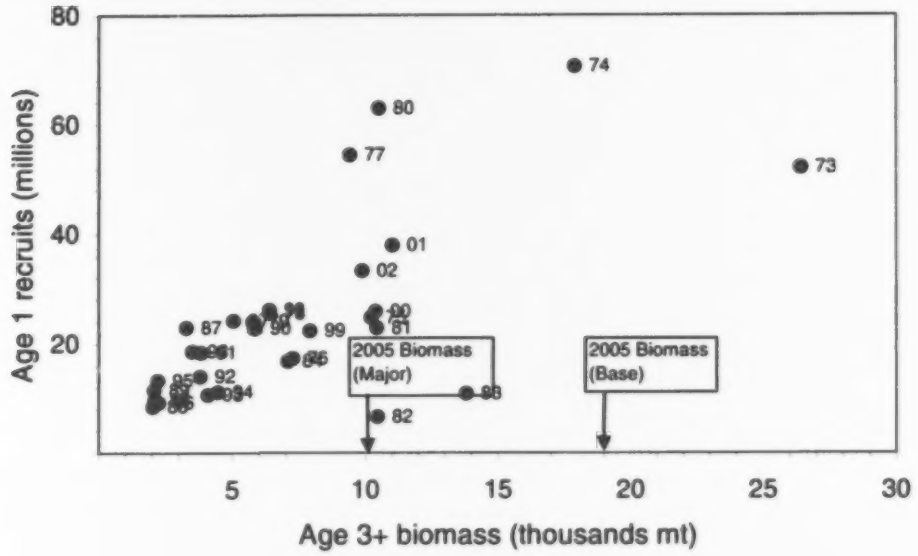

Fig. 41. Age 3+ biomass and age 1 recruitment relationship for Georges Bank yellowtail flounder from the Base VPA formulation. The beginning of year age 3+ biomass for 2005 from the Base VPA and Major Change VPA is also shown.

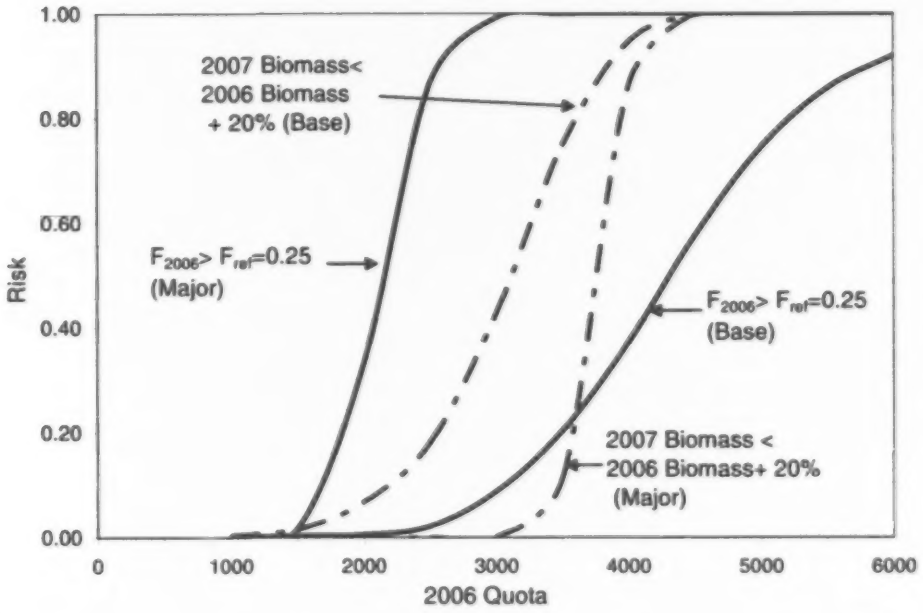

Fig. 42. Risk of exceeding F_{ref} fishing mortality or not achieving increments of age 1+ population biomass growth from the Base VPA and Major Change VPA model formulations, at various quotas for the 2006 fishery for Georges Bank yellowtail flounder.

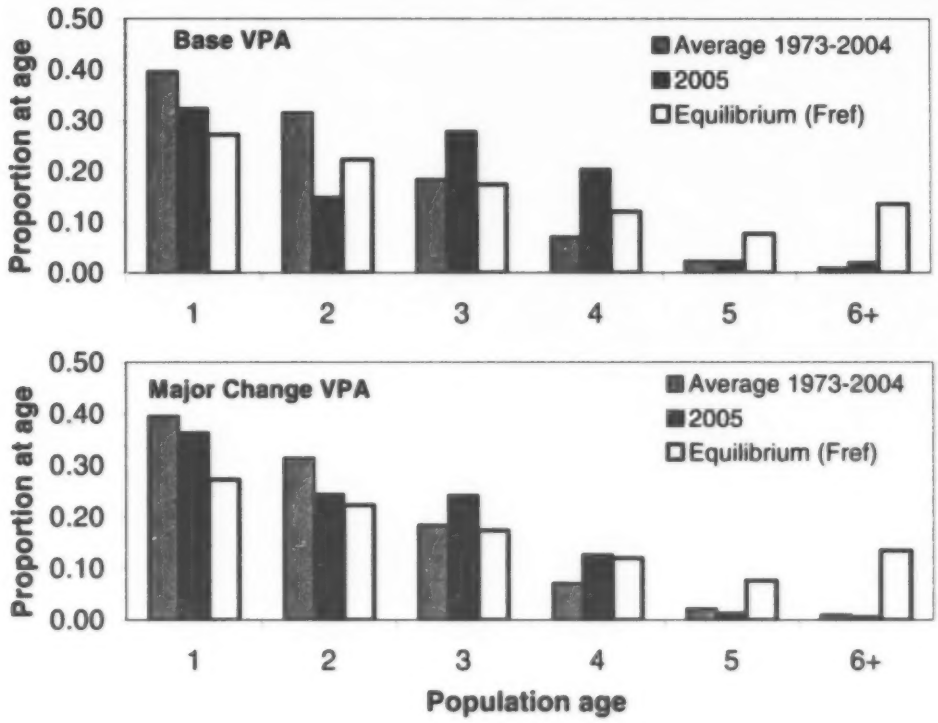

Fig. 43. Proportions at age for the Georges Bank yellowtail flounder population in 2005, for the average of 1973-2004 and when the population is at equilibrium, based on results from the Base VPA (upper panel) and Major Change VPA (lower panel).